A decision algorithm for Nuclear, Biological, and Chemical decontamination using dynamic programmi

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A DECISION ALGORITHM FOR NUCLEAR, BIOLOGICAL, AND CHEMICAL DECONTAMINATION USING DYNAMIC PROGRAMMING

by

John Crawford Roberts

September 1988

Thesis Advisor: Samuel H. Parry

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A Decision Algorithm for Nuclear, Biological, and Chemical Decontamination using Dynamic Programming

by

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Captain, United States Army
B.S., University of Tampa, 1982

submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis describes a decision algorithm developed to schedule land combat units for Nuclear, Biological, and/or Chemical (NBC) decontamination. It is an application of the Generalized Value System (GVS) of assigning unit value and power over time. The actual model is a PC based FORTRAN model that determines the optimal scheduling of contaminated units using a dynamic programming technique. Optimal in this application means minimal total time required for the decon operation. The schedule developed is based on the latest possible start time, thus allowing for the most flexibility. The model is a high resolution stand alone type. It depicts up to six units with three different vehicle types, ten or more decon sites, and one decon team. The terrain is modelled as an undirected network and has distance and trafficability attributes.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logical errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

A. NBC WARFARE AND DECONTAMINATION

Some form of NBC (Nuclear Biological Chemical) warfare is inevitable on the modern battlefield. Lack of reliable historic data and other uncertainties make modelling of these effects critical. Chemical agents can be disseminated by bulk in missiles, dispersed by artillery shells or rockets, sprayed by low flying aircraft, or even spread by mines.

These agents can be classified as either persistent or non-persistent. Non-persistent agents are gaseous and highly volatile. They are used primarily to surprise troops not wearing respiratory protection or against ill-equipped armies. Non-persistent agents are not a concern for NBC decontamination.

Most modern chemical agents (and biological toxins) are of a liquid type. They produce casualties from contact through the skin or by inhalation of the aerosol. Several drops the size of a pin head can kill. Depending on weather conditions, these agents can linger for days and in some cases weeks. Decontamination of these liquids is required to avoid the clumsy and confining chemical protective gear.

Nuclear weapons produce fallout that also requires removal. In this case, a quick removal is preferred since chemical overgarments do not protect against gamma radiation. Chemical decontamination is accomplished by removal (soap and heated water under high pressure) and/or neutralization by other (usually caustic) chemicals. The U.S.

Army uses DS2 for this. Weathering can also be thought of as a form of decontamination. Decontamination is not reliable in all cases, is difficult to perform for some delicate equipment, and consumes time and resources. It is required, nonetheless, in an NBC environment.

Decontamination is classified into three categories. The first is basic soldier skills which are essentially individual self decon. The second category is hasty decontamination. The idea here is a quick cleaning to remove the "gross" contamination. Only hot soapy water is used. No neutralizing agent (DS2) is used since its effects require a wait time of twenty minutes. Hasty decontamination requires the use of Power Driven Decon Equipment (PDDE). Each maneuver battalion is equipped with one such device. The PDDE is operated by the battalion decontamination team. It is this battalion team that is *primarily* represented in this model. Other similar decon support is also provided by division and/or corps decon assets. The higher echelon decon assets may augment the lower (battalion) level assets.

The highest level of decontamination is deliberate decontamination that supposedly removes the agent. This is virtually a refit process since all porous materials must be replaced because they are impossible to decontaminate. Further, after application of the DS2, some sort of maintenance may be required since the DS2 will tend to strip the surface of all lubricants. Finally, some contaminated equipment components may have to be replaced if they are susceptible to hot soapy water under pressure. Deliberate decon is performed by a decon platoon from a division or corps NBC decon company. It is heavily assisted by brigade logistical assets. One deliberate decontamination mission usually

involves an entire battalion or a collection of units whose aggregate is comparable to a battalion. Anything smaller is usually not worth the effort.

Disposal of contaminated items like canvas, chemical suits, and control of contaminated waste water is required. The decon site will have to be chosen so as to eliminate any possible nuisance from these items. This is especially true for a deliberate decon operation.

B. STATEMENT OF PROBLEM

The problem to be addressed is not the actual modelling of a decontamination operation, but rather the planning aspects of the operation. Given a collection of units in a battle area and one decon team, where should each unit undergo decontamination and when? In other words, what combination of sites and units will complete decon the fastest, given that there is only one decon team? How long can the commander wait before initiating the process without suffering excessive degradation? How will the model measure this degradation?

This thesis will expatiate on the algorithm that was produced in order to investigate this problem. The decontamination decision algorithm is a PC based FORTRAN program. Given a land combat scenario, it will produce an optimal schedule for unit decontamination at a choice of various surveyed sites. Optimal in this context refers to a unit ordering that produces the fastest decon time, and a schedule that allows for the latest start time that is feasible. The assumptions for optimality and feasibility will be explained in Chapter 2.

This algorithm uses dynamic programming and the Generalized Value System (described later) to solve the problem. It may be utilized for

either hasty or deliberate decontamination. By making multiple runs, it may also solve scenarios with multiple decon teams.

C. BACKGROUND

The motivation for this research was to upgrade the Vector In Command (VIC) model. VIC is a corps level deterministic model written in SIMSCRIPT II.5. Hasty and deliberate decontamination is currently modelled in VIC. However, the decision criterion for decontamination is somewhat over simplified. Decon is performed "at the earliest tactical opportunity." [Ref. 1]

The model presented here is a stand alone model. It cannot be readily integrated into VIC since VIC does not allow for a look ahead feature in its decision logic (i.e., the application of the Generalized Value System in this model).

II. METHODOLOGY

A. INTRODUCTION

Selecting a site for decontamination operations is a complex process. First of all, there are many possible solutions. Some of these will be better than others, depending on what is considered best. Therefore, a methodology must be chosen to accommodate a broad spectrum of decision criteria. Secondly, besides being "optimal", the choice of solutions will have to meet certain constraints. In the case of NBC decontamination, this would include unit degradation and casualties.

This decision model uses a dynamic programming technique to implement the desired measure of effectiveness and choose a solution. A dynamic program is flexible enough that various measures of effectiveness (MOEs) could be used without changing the model structure. The MOE used in this model will be discussed in depth later. The Generalized Value System provides the means used to define the feasible region. Various networking techniques, such as Dijkstra's algorithm, and various abstract data types, such as a hierarchical adjacency list, were also used.

B. DECISION CRITERIA

A feasible solution will be such that decontamination is performed before combat effectiveness degrades to unacceptable levels. However, the frequency of decontamination operations should be as low as possible, allowing resources to be concerned with winning the battle

rather than being clean. Army Field Manual 3-5 [Ref. 2] provides some very general guidance in this area with four basic principles as follows:

- Decontaminate as soon as possible.
- Decontaminate only what is necessary.
- Decontaminate as far forward as possible.
- Decontaminate by priority.

Performing decontamination "as soon as possible" is too vague to be translated into the model. The idea behind that principle is that the chemical agent will (in most cases) imbed itself in metallic surfaces in about an hour. If decon is performed before this time, it will be much easier to remove the agent. Providing complete decon support within one hour will prove to be impractical in most tactical situations.

To "decontaminate as far forward as possible" seems reasonable. However, it must realized that a decontamination operation will only be performed where allowable. In general, if the decision criteria are chosen carefully, then this principle could be met automatically.

There are various discriminators that can be used to determine the optimal solution. The following were adopted for this model:

- Decontaminate only as required.
- Decontaminate by priority.
- Minimize total time required for decontamination while maintaining feasible combat power.

Here units are prioritized by the time at which combat power reaches infeasible levels. Hence, a unit going infeasible at hour 10 has priority over a unit going infeasible at hour 12.

C. APPLICATION OF THE GENERALIZED VALUE SYSTEM

The Generalized Value System (GVS) is due to Prof. A. L. Schoenstadt [Ref. 3] and Robert A. Kilmer [Ref. 4]. It provides a method of assigning a value to an "entity". An entity can be either a unit or some object that contributes to combat enhancement (e.g., a bridge). The decon decision model uses this method to update the value of a unit based on its exposure to NBC hazards. Decisions can then be made based on predicted "unit power". The concept of GVS is described below.

In GVS, there is derived power and inherent power. Each entity may have one or both of these, the sum of which is the total power. Based on the usefulness of the unit for a given situation, the total power is adjusted yielding the "value" of the unit. Basic Inherent Power (BIP) is the combat power associated with each unit. That is, it is the unit's ability to inflict damage on other entities. Derived power, on the other hand, is the power that an entity may provide to other friendly units. For example, a bridge could have derived power that it provides to mechanized units.

This model utilizes the inherent power of the units in question. The inherent power will be modelled by exponential discounting [Ref. 4]. In each model scenario, all units will start with an Adjusted Basic Inherent Power (ABIP), build up to its BIP, and undergo various changes in power over time. The unit power at a given time will be termed the Situational Inherent Power (SIP).

The unit power is modelled in three stages. The first stage is the unit moving from its adjusted basic inherent power (ABIP) to realizing its full basic inherent power (BIP). This could be either moving into position or being reinforced (see Eqn 2.1). The second stage occurs after the NBC attack, where the unit suffers degradation due to being in some sort of protective posture. Note that the model allows for the unit to be attacked before realizing full BIP. The third stage occurs at the point where unit casualties are realized due to agent effects. These three stages are described by the following equations.

Stage One. $CSIP = ABIP \times e^{(B(i) \times (t - To))}$ (Eqn 2.1)

The coefficeint B(i) is dependent on the ABIP and BIP for unit i. B(i) is calculated as follows:

$B(i) = (\ln(BIP/ABIP))/(\text{Ready Time for Unit i})$ (Eqn 2.1a)

Stage Two. $CSIP = BIP \times e^{-(DEG \times (t - Td))}$ (Eqn 2.2)

(or) $CSIP = SIP \times e^{-(DEG \times (t - Td))}$ (Eqn 2.3)

The second stage 2 equation (Eqn 2.3) is used when the units are attacked before BIP is reached. SIP in this case is the power the units realized up to the time of attack.

Stage Three. $CSIP = SIP \times e^{-((ATT(i) + DEG) \times (t - Ta))}$ (Eqn 2.4)

where

CSIP ≡ Current Situational Inherent Power

BIP ≡ Basic Inherent Power (realized at unit ready time)

SIP ≡ Situational Inherent Power

B(i) ≡ Rate of power increase for unit i due to movement and/or reinforcement

ATT(i) ≡ Rate of power decrease due to attrition for i^{th} unit

DEG ≡ Rate of power decrease due to MOPP degradation (Assumed to be the same for all units).

t ≡ Current time

T_0 ≡ Start of planning window (always 0 as applied in this model)

T_d ≡ Time when degradation starts (attack time from T_0)

T_a ≡ Time when attrition starts, from T_0

The stage one equation (Eqn 2.1) is taken directly from Kilmer [Ref. 4]. Stage two (Eqn 2.2 or 2.3) describes the unit being degraded due to being in an NBC protective posture. It is assumed that all units will be affected equivalently in terms of degradation. Therefore, the degradation coefficient is a global one. The stage three equation (Eqn 2.4) represents the unit undergoing attrition *and* degradation. At this point, the chemical protective gear slowly becomes compromised, producing casualties. The stage two and three equations each show decreasing degradation and attrition over time (i.e., as time progresses the rate of the agent effects diminish). This occurs for two reasons. First of all, the agent will begin to weather away with time. Secondly, actual data shows that the rate of unit degradation tapers off as the unit becomes acclimated to the protective posture [Ref. 5]. Figure 2.1a

shows a typical unit power plot with all three stages of power decay. Figure 2.1b illustrates the case of a unit being attacked before realizing full BIP. In this case, the unit never attains its full BIP. Other than that, the rest of its power degradation is the same.

A threshold value is chosen for each unit and is defined as a percent of unit BIP (e.g., unit power must not go below 50% of its BIP). When the final schedule for unit decontamination is calculated, the schedule will be as late as possible without violating the unit thresholds, unless the decon time between units is too great. It is possible that large decon times and/or high degradation rates make it impossible to decon all units in time. At the other extreme, there may be no threshold violation during the planning horizon. In that case, no decontamination is necessary within the planning window. Figure 2.1a also shows a typical threshold value in relation to unit power.

Hasty decontamination will restore unit power, but only up to a certain percentage of the unit BIP (or CSIP if unit is attacked before realizing BIP). Restored power is a result of relief from chemical protective posture. The fraction of power restored is a parameter input to the model.

It is assumed that decontamination will halt further degradation. In reality, some limited protection probably will be required after a hasty decon operation. As stated earlier, degradation tapers off as the unit acclimates. Furthermore, any protection required after a hasty decon will be reduced. Therefore, any further degradation after

Figure 2.1a
Typical Power Plot

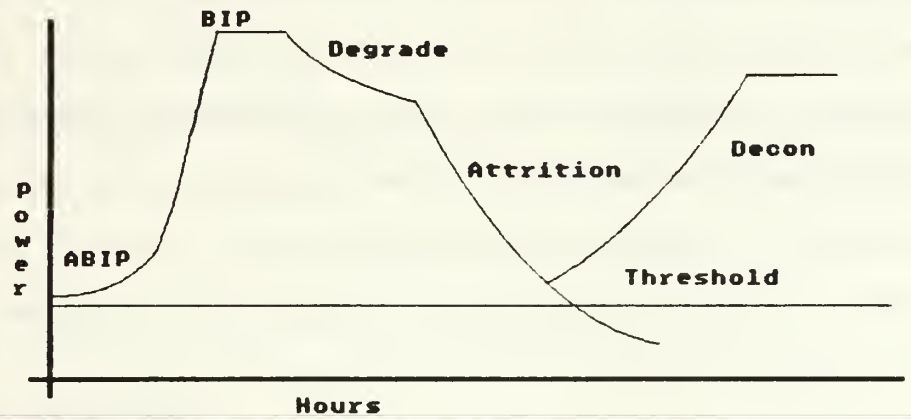


Figure 2.1b
Attack before ready time

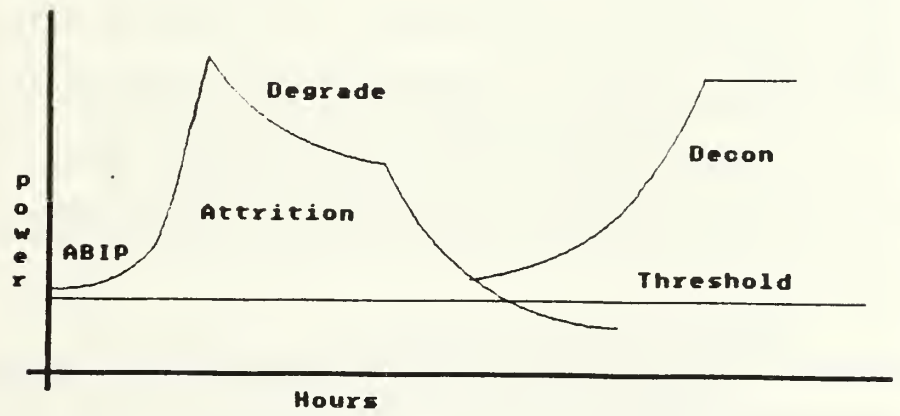


Figure 2.1 Unit Power Plot Examples

even a hasty decon will be negligible. The model also provides for an abbreviated decontamination (i.e., less time per vehicle), resulting in less restoration. The decon process itself is modelled as an exponential function from zero restoration for zero decon to full restoration for 100% decon performed. The equation is the same as the one used to bring the unit up to full BIP except for a different exponent (Eqns 2.5 and 2.6). Note that it is possible to undergo decon well before stage three degradation occurs.

$$RSIP = SIP \times e^{(R(i) \times DTIME(i))} \qquad \text{(Eqn 2.5)}$$

where

RSIP ≡ Restored SIP

R(i) ≡ Restoration rate for unit i

DTIME(i) ≡ Required decon time for unit i

and

$$DTIME(i) = (\#\text{ veh type 1}) \times (\text{time per veh type 1}) + (\#\text{veh type 2}) \times (\text{time per veh type 2}) + (\#\text{veh type 3}) \times (\text{time per veh type 3}) \qquad \text{(Eqn 2.6)}$$

The unit decon time is based on the number of vehicles in the unit (Eqn 2.6). The total restoration is a fraction of unit BIP (Eqn 2.7).

$$RSIPmax = BIP(\text{or SIP at attack time}) \times (\text{fraction restoration possible}) \qquad \text{(Eqn 2.7)}$$

The rate coefficient R(i) is determined by Eqn 2.8.

$$R(i) = (\ln(RSIPmax(i))/(SIP(i) \text{ at decon time}))/DTIME(i) \quad \text{(Eqn 2.8)}$$

One interesting case occurs when it is not possible to decon all vehicles before their threshold time. In that case, the decon time may be shortened. Although less recovery will be realized, it may then be possible to complete all units with no threshold violation.

D. OTHER ASSUMPTIONS

Realism is always desirable when constructing a model. Practicality however, usually takes priority. There are several fundamental assumptions for this model as described below.

It is assumed that all units will collectively be performing some mission. Before the start of the mission they will spend some amount of time preparing and/or moving into position. Then at a given time, the units will be ready to perform this collective mission.

It is further assumed that after this ready time, one of two cases will occur: either

- Case (1): the units as an aggregate group will remain in the area of operations; each unit will be in its designated location when the decon operation starts.
- Case (2): the aggregate group will leave the area of operations.

Regardless of which case applies, all units will undergo an NBC attack *simultaneously*. Note that Case (1) is not necessarily a static

scenario. Any or all of the units may move around as required by the tactical situation. For example, assume all the units sustained an NBC attack at time four. If unit two is scheduled to *move out* for decon at time 13, it may be anywhere in the area of operations as required by its mission prior to this time. It must, however, be at its designated unit position no later than time 13. Furthermore, when unit two completes decon, it is once again free to go anywhere.

In the second case, all units undergo decontamination in route to the next area of operations. This case does not require the use of the dynamic program routine. All units form a queue at a designated site closest to the point of departure. The model will then attempt to schedule all units to go through decon so that the departure time can be met. All units will be scheduled for decon before reaching the power threshold, regardless of departure time. The units will be scheduled in order of closest to furthest from the designated decon site. Since there is only one solution in this case, it will not be addressed any further.

When the decon operations start, the units will only be allowed to pull out one at a time. The next unit will not leave until the previous unit completes decon. Note that the last unit scheduled for decon will undergo power loss for the longest amount of time. Therefore, when scheduling units for decon, the latest start time is determined so that all units start decon at the site no later than the threshold time.

Obviously, the earliest time the decon operation can begin is at the time of the NBC attack. If a unit is last in the decon schedule, it still may fall under its power threshold even if the operation begins

immediately. Realistically, the attrition and degradation coefficients would have to be rather high for such a case to occur. The magnitude of degradation and attrition coefficients required to cause this situation is addressed in Chapter 3. This *may* be corrected by changing the unit order. The model, however, will not do this. The schedule for decon is always such that the overall time required is minimized. No unit is favored in lieu of the optimal ordering.

The unit decon times are based on the number of vehicles in that unit. There are three different vehicle types that are used by the model. The decon time required for soldiers and vehicle crew is included in the vehicle decon time. Note that total time for the operation includes not only actual decon time, but travel time and water resupply as well (the decon apparatus requires a large amount of water). A very important assumption is made about unit travel time. It is assumed that the units and the decon team will always choose the fastest path when travelling between two points on the map. It is this information that is given to the dynamic program recursion. Note that the fastest path is not necessarily the shortest path. Some routes on the map have higher speed limits than others due to terrain. This point will be discussed later in this chapter.

Each decon site is given an associated site attribute coefficient (see Eqn 2.9).

$$\text{adjusted DTIME}(i) = \text{DTIME}(i) \times \text{ATTRIB}_{\text{SITE}(i)} \qquad \text{(Eqn 2.9)}$$

$\text{ATTRIB}_{\text{SITE}(I)} \equiv$ Attributes factor for site i

This attribute is a factor that adjusts the decon time for any positive or negative site attributes. In the base case scenario, the site attributes are all set to one. This means that the decon time at site one, for example, is no different than the decon time at site two. The site attribute has nothing to do with the travel time to the site or water resupply.

Water, decon sites, and the decon team are the only resources considered in the model. Other logistical constraints are not considered in the current model. One possible way to model these effects would be to adjust the site attributes. For example, if a decon site is not well stocked with chemical protective suits or resupply of individual equipment (web gear, etc.), there will be a time penalty associated with resupply. This could be reflected by setting the site attribute to some value larger than one.

Although the model is concerned primarily with hasty decontamination, deliberate decontamination can be modelled in much the same way with three exceptions. First, hasty decon only gives a partial restoration. Deliberate will (supposedly) provide full restoration, since some protection from residual contamination will still be required in the case of hasty decontamination.

Secondly, deliberate decontamination time will depend greatly on the site chosen. For instance, a car wash in an urban area will expedite a deliberate decon operation much better than a site out in the woods. A hasty decon does not require as many resources, and a site in

the woods would probably suffice. Here again, this could be represented by the site attributes.

Finally, there is a setup time for the site for a deliberate decon operation. This is reflected in the per vehicle decon time since the amount of preparation is proportional to the size of the unit coming through.

E. NETWORK REPRESENTATION OF MAP

The area being modelled is an undirected network (see Figure 2.2) [Ref. 5:p. 17]. The map contains 34 nodes and 72 arcs. This means that a unit can be at one of 34 discrete locations or in route to one of them on one of the arcs.

The sites can be at any of the nodes. Once a site is designated at a particular node, it stays at that node for the duration of the simulation. If the aggregate unit (i.e., the collection of units) is to move during the planning horizon, then one of the designated sites is chosen closest to the departure point.

Each arc not only possesses a distance but a trafficability constant as well (e.g., it may take less time to travel a longer distance). It is assumed that the trafficability of the arc is the same in both directions. This may or may not be a good assumption depending on the terrain profile.

Although the original network map has undirected arcs, it is read in and treated as a directed graph. That is, there is one arc for each direction between connected nodes (Figure 2.3). For example, if node three and five are connected, then there will be two directed arcs associated with the path between those two nodes, one for each

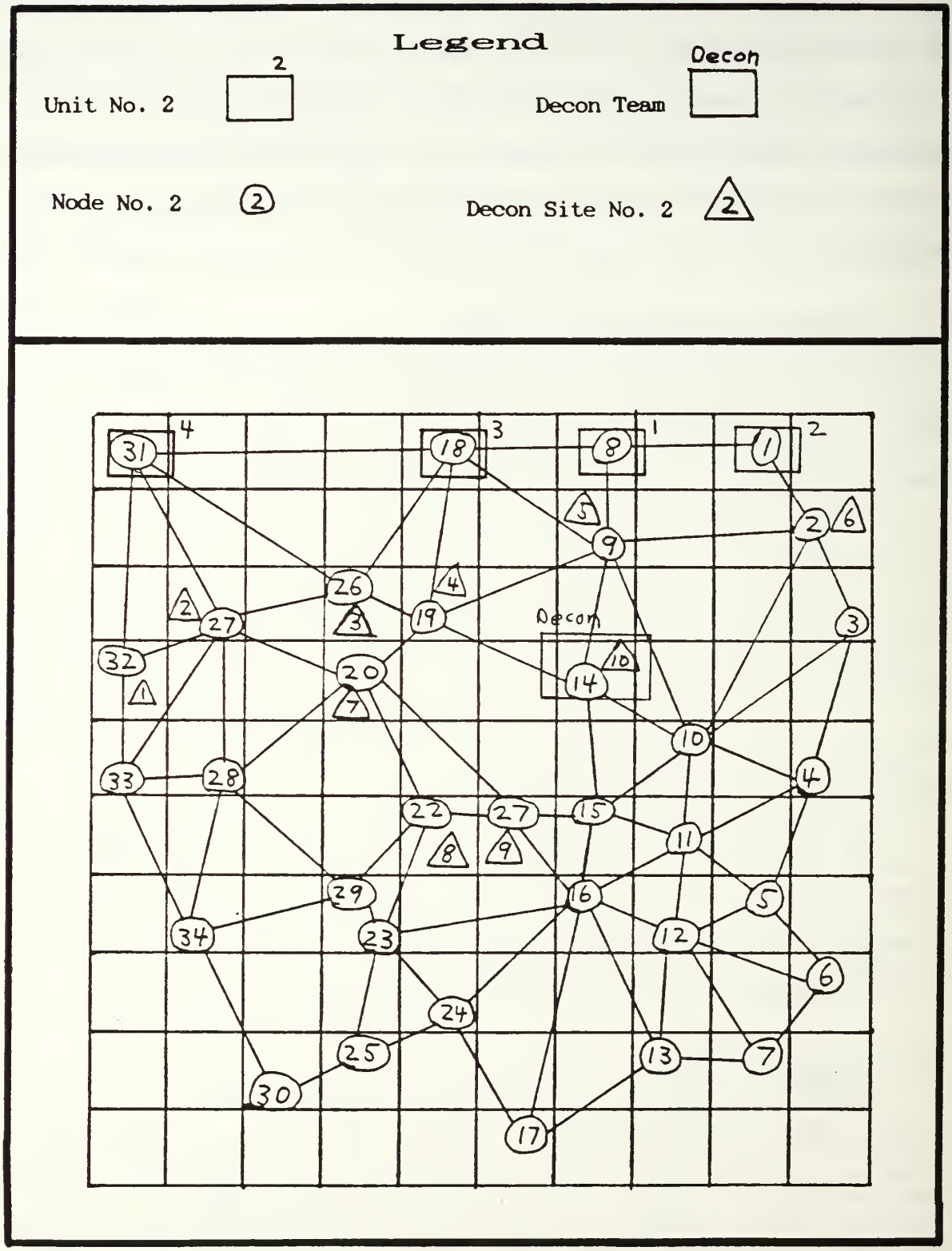


Figure 2.2 Network Map

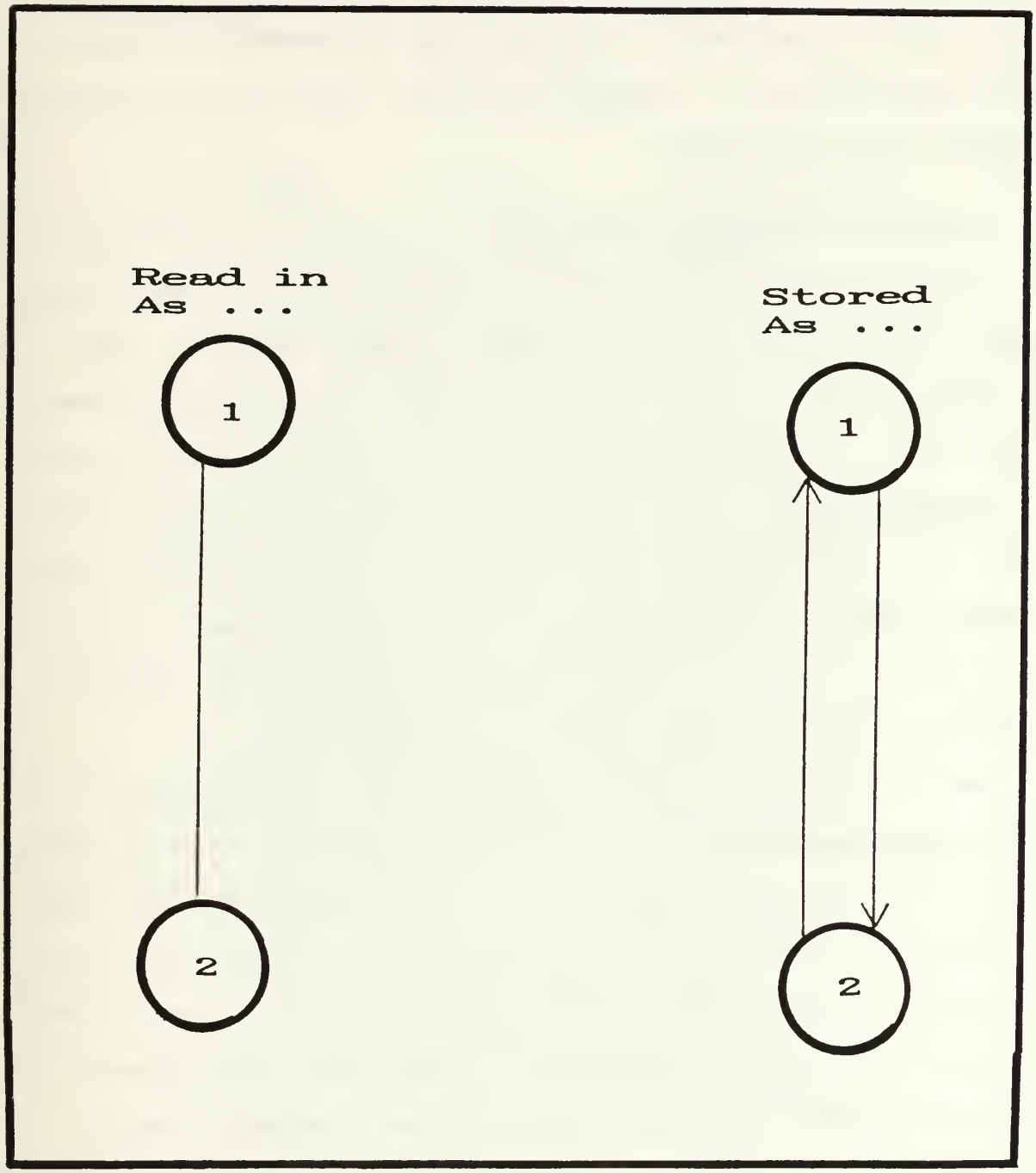


Figure 2.3 Map Arcs

direction (three to five and five to three). This will allow Dijkstra's algorithm to be used since it requires that the network be a directed graph (see section G). The model, therefore, stores 144 arcs for the scenario used in this model.

F. DYNAMIC PROGRAMING TECHNIQUE

The ordering of sites and units providing the fastest total decon time for all units is found by using a dynamic program. Using a heuristic algorithm with a "greedy approach" will probably not work [Ref. 7:p. 5]. A greedy approach assumes that what is optimal locally is optimal globally. That is, picking a scheme that starts with the decon site closest to the first unit may well not be the best solution overall. A dynamic program will find an "optimal" solution, given that one exists. This eliminates the need for a heuristic algorithm that may or may not find an optimal solution.

As with all dynamic programming (DP) graphs, the model consists of various stages containing several states. Figure 2.4 illustrates a case with three units and three decon sites. In this example, the decon team is initially at site two. Each stage represents the number of units left to under go decontamination. The number of stages is therefore the number of units plus one. Each state represents which units remain to undergo decon and the site where the decon team is currently located.

Each tail, arc, and head combination in the DP graph represents the time required to decon a particular unit at a particular site, given the decon team is in its current location. When going to the next stage, the decon team starts at the place indicated in the "from" state (or tail node). The site indicated in the "to" state (or head node)

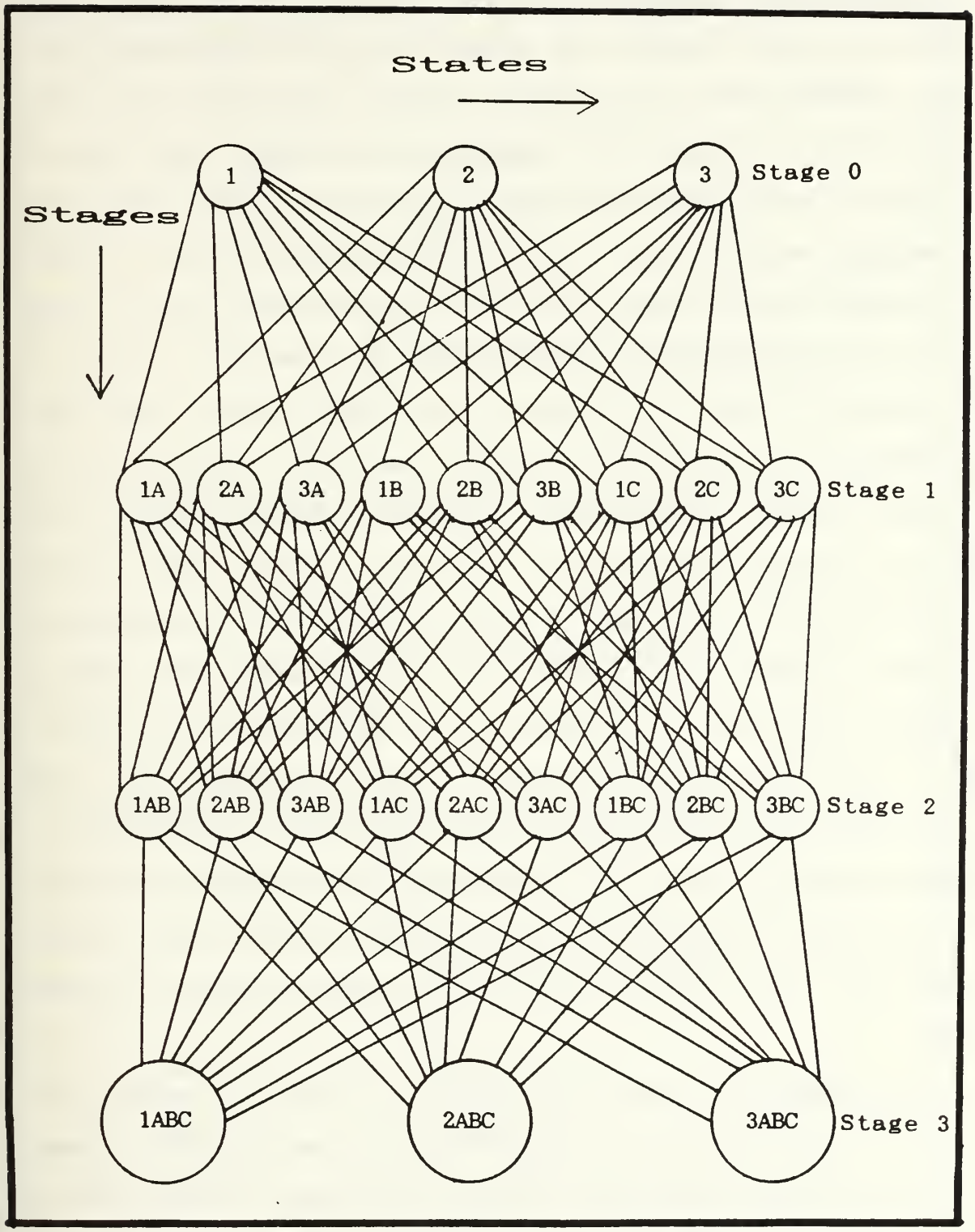


Figure 2.4 Dynamic Program Graph

is the site where the next decon operation is to be performed. The difference between the unit list in each of the states determines which unit undergoes decon. For example, the arc that connects the state denoted by "1AC" to state "3A" represents the following; Units A and C are left to decon and the decon team is currently at site 1. Then unit C undergoes decon at site 3. The next decon operation (i.e., the tail of the next arc) will then start with the decon team at site 3. Note that it is impossible to go from state "1AC" to state "2B". That is, it is impossible to have unit B left to decon when if units A and C were originally the only ones left to go (see Figure 2.5). Given the above notation, the DP recursion will determine the optimal ordering. The goal is to minimize *the sum* of the arcs (i.e., minimize time). In the case of three decon sites and three units (Figure 2.5), it is desired to connect the state in the first stage that represents the starting scenario (state "2ABC") to stage zero which represents no units left to decon. The process starts in stage one, state one (state "1A"). The "least cost" (or minimum time) arc from that state into stage zero is found by comparing every arc into stage zero from that particular state. In the example in Figure 2.4, there are three possible arcs from the state "1A". This is done for every state in stage one going into stage zero.

The process is repeated for stage two. This time, however, the arcs are chosen to minimize the *sum* of the arcs from the states in stage two all the way to stage zero. That is, the arc value from the state in stage two to the chosen state in stage one is added to the arc previously calculated above for the state in stage one. See Figure 2.6

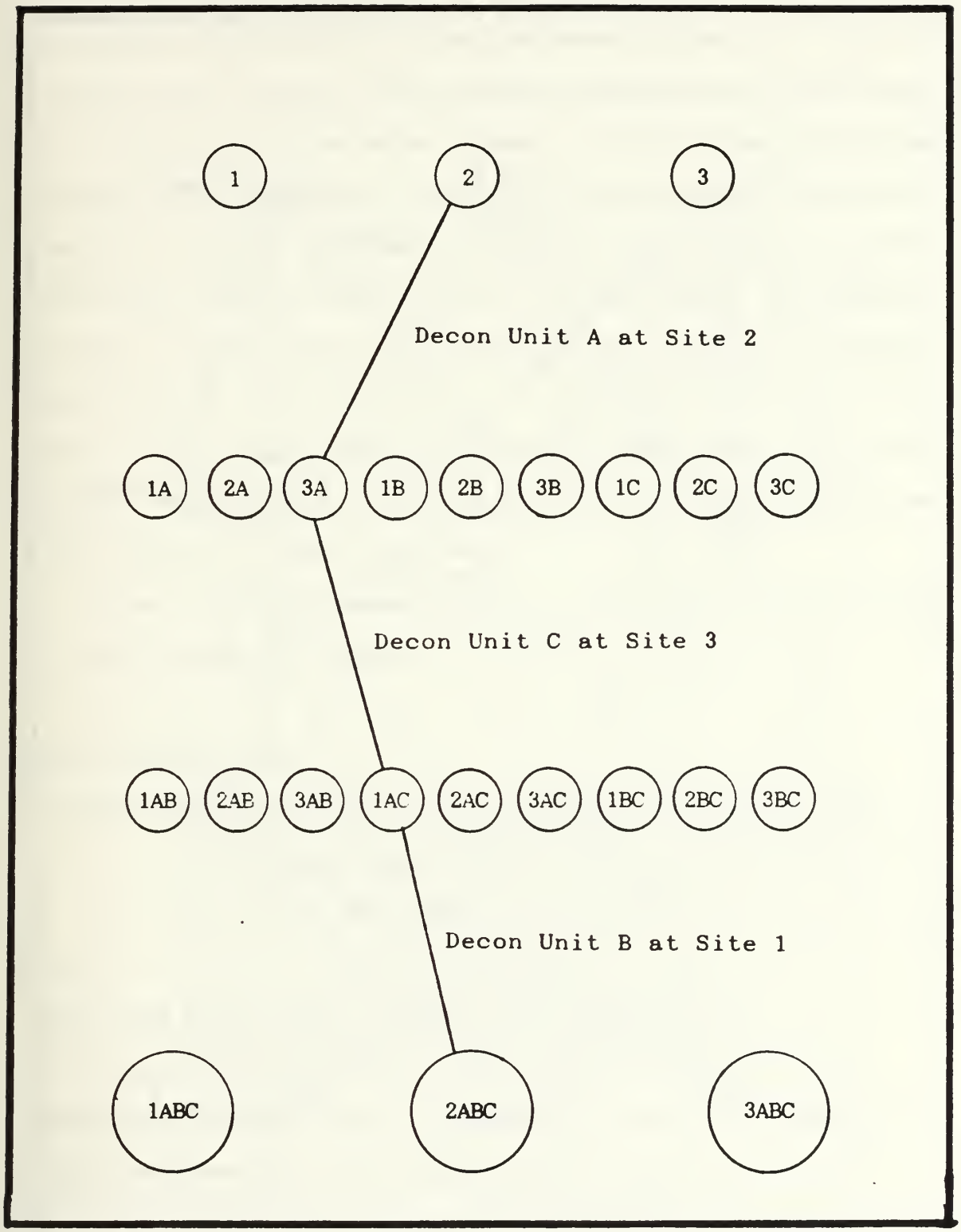


Figure 2.5 Solution Path Example

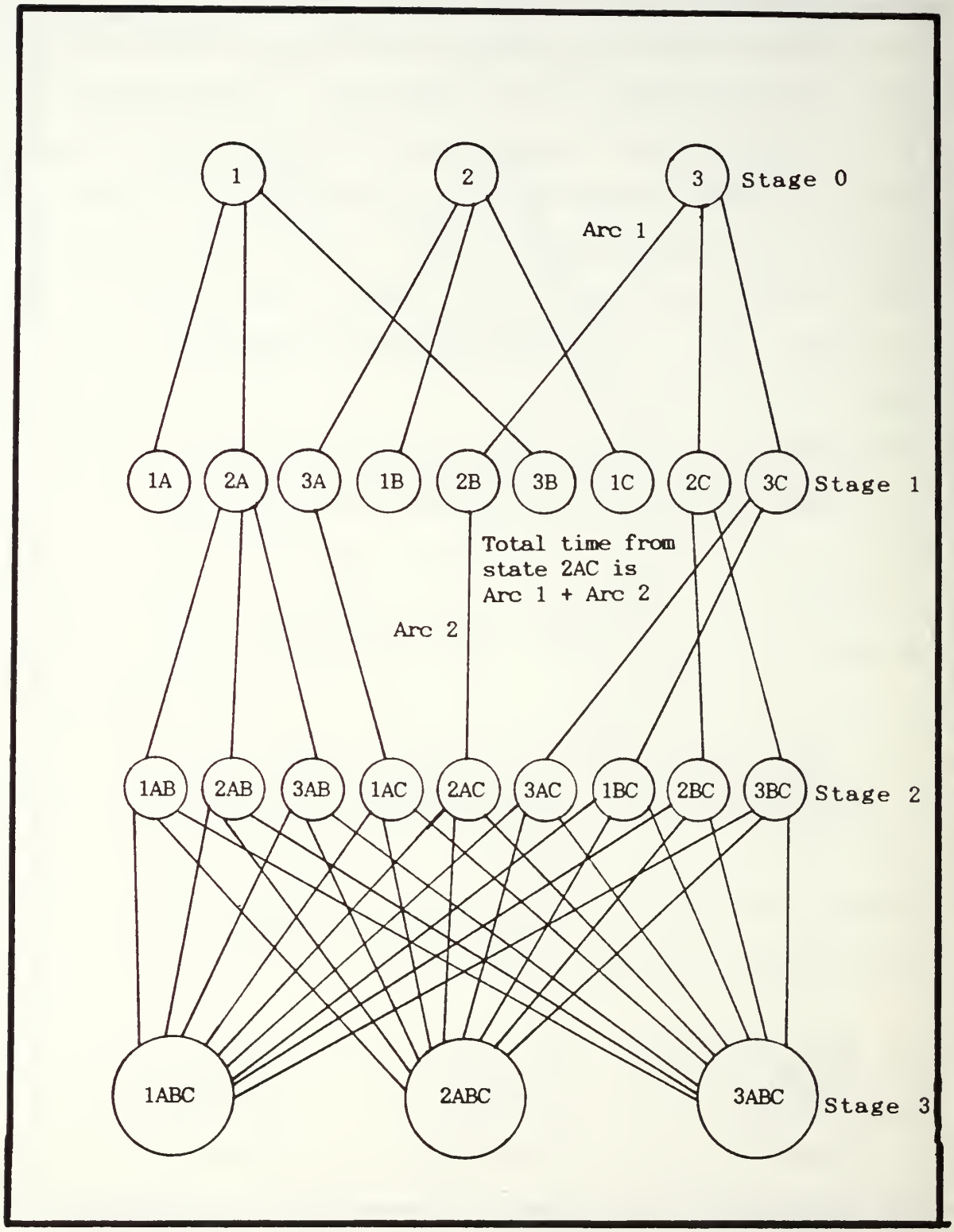


Figure 2.6 First Two Stages Solved

for an example. The DP chooses the minimum *sum* of all the arcs from the given start state all the way to the last state in stage zero. In order to do this, the arcs out of the previous state must have been chosen. This is, therefore, a recursive process. It starts from the end and works back to the beginning. In this way every possible combination is considered. Finally, in stage 3 the state corresponding to the decon teams initial location (state "2ABC" in this example) is considered. That final arc will connect a unique optimal solution *given a particular initial location for the decon team.* It is possible to pick a starting location for the decon team that will result in the unconditionally best solution. That application is beyond the scope of the problem addressed in this thesis.

The units must be processed one at a time. The total decon time for a unit is shown in equation 2.10.

TOTAL DECON TIME(i) =

MAX[(DECON TEAM TRAVEL TIME),(UNIT TRAVEL TIME)]
+ (WATER FACTOR)x(WATER RESUPPLY TIME) + HDTIME(i)
+ (UNIT TRAVEL TIME) (Eqn 2.10)

where:

DECON TEAM TRAVEL TIME ≡ Travel for decon team to site.

UNIT TRAVEL TIME ≡ Unit travel time to *and* from site.

WATER FACTOR ≡ Equals zero if water is not required or one otherwise.

WATER RESUPPLY TIME ≡ Time required for the decon team to fill its tanks with more water.

The frequency (in number of unit missions) of water resupply is an input parameter of the model. The amount of time for water resupply is based on the decon time for each vehicle. This follows since the longer the decon time, the more water that will be required for a given number of missions. This translates into a longer time for water resupply.

It is obvious from Figure 2.4 that the number of states increases combinatorially as the number of units increase. Each stage will have

nCs x (number of sites) (Eqn 2.11)

where

n ≡ number of units

s ≡ stage number

The notation nCs represents the binomial coefficient.

The current PC based model processes up to six units and ten sites, due to memory requirements. If the DP were written to a file and only brought in as required, then virtually any size problem could be handled. The run time for the algorithm is proportional to the number of states in the DP graph. This is because the most time consuming or dominant task in the algorithm is the comparisons done in the DP recursion. The computer time required for the process will therefore also increases combinitorially with the number of units. But even the six unit, ten site model required less than a minute to run. For high resolution applications six units is a reasonable upper limit.

The number of states in the DP graph increases proportionally with the number of decon sites. This follows from equation 2.11. Increasing

the number of sites from ten to 20 would not pose a problem. That is, if a combinatoric increase produces tolerable run times, a linear increase would practically be negligible. However, ten sites should suffice for most high resolution scenarios.

G. OTHER PROGRAMMING TECHNIQUES USED

An incidental problem is the question of *how* to determine the travel time between the units and sites on the network map. Calculation of these times was accomplished using Dijkstra's algorithm. Dijkstra's algorithm determines the shortest path from a single node in a directed network to all other nodes. In this application, each arc value on the network map was converted from distance to time. Notice that if the desired MOE was to minimize the spread of contamination, then distance rather than time would be used on the arcs. Most MOEs will require either time or distance between the units and decon sites.

Dijkstra's algorithm partitions the network map between the start point and all other points. With each iteration of the algorithm, another node is brought into the partition with the start point. The arc is chosen such that the resulting path in the partition is the shortest. All paths are then updated with each additional node brought into the partition [Ref 6:pp. 203-206]. The time required to execute Dijkstra's algorithm is proportional to the number of nodes squared. One important note about Dijkstra's algorithm is that it will not work with negative arc values [Ref. 7:p. 205].

The map network and the DP network are both stored in a hierarchical adjacency list (see Figure 2.7). This data type consists of two arrays, the Entry Point (EP) Array and the Head (HEAD) Array.

The element in cell N of the Entry Point Array is the entry point in the Head Array for node N. This cell entry points to the first node (numerically) adjacent to node N. The list stops one cell before the entry point for node N+1. If node M were to have no adjacent nodes, then the start point for M would be the same as for M+1.

With this type of representation, all adjacent nodes to a given node can be accessed in a FORTRAN DO loop. The DO loop for node N would run from HEAD(EP(N)) to HEAD(EP(N+1)-1). Notice that in the example above for node M, the DO loop would not execute, since node M has no adjacent nodes.

The DP network does not require a HEAD array. This is because every node for stage one through N (for N units) has exactly one head node.

The network map represents the path between two nodes by two arcs (Figure 2.3). Only one direction is read in during input. That is, the arc from node two to ten is read in as (2 to 10) and the arc (10 to 2) is automatically implied. So even though the model works with a directed graph network map, the arcs to the network map are input as an undirected graph. This reduces the input file to the network map by a factor of two. The model input automatically stores which nodes are adjacent to each other. To accomplish this, the edge list is read twice. The first time, the degree of each node is determined [Ref. 7:p. 105]. The second time, the forward star representation of the node is stored. The forward star representation of a node refers to the arcs going *out of* that node. The edge list in this representation would read

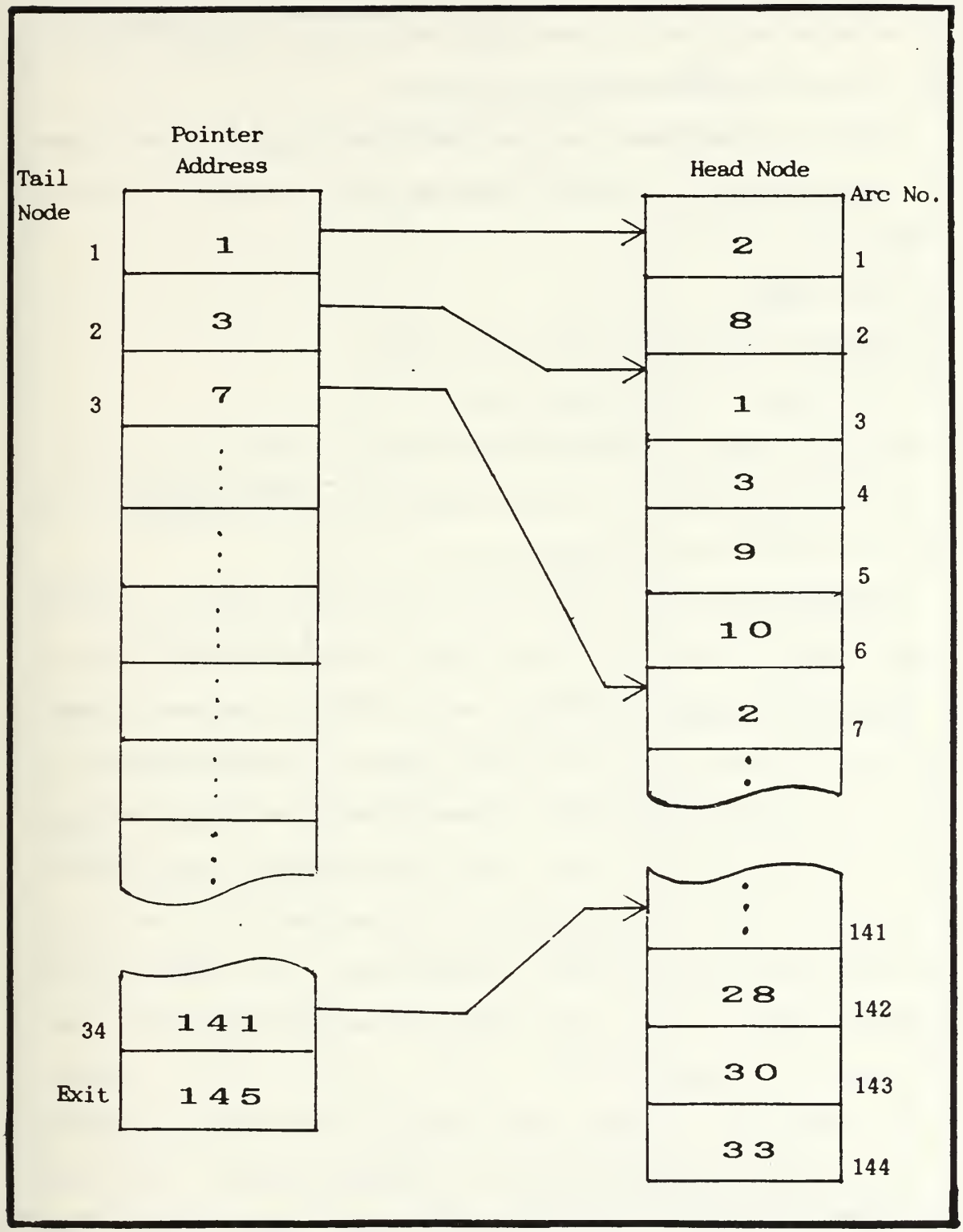


Figure 2.7 Map Network Arcs

tail node to head node. This is in contrast to a reverse star representation which is the arcs going *into a* node. In this case, the edge list would read head node to tail node.

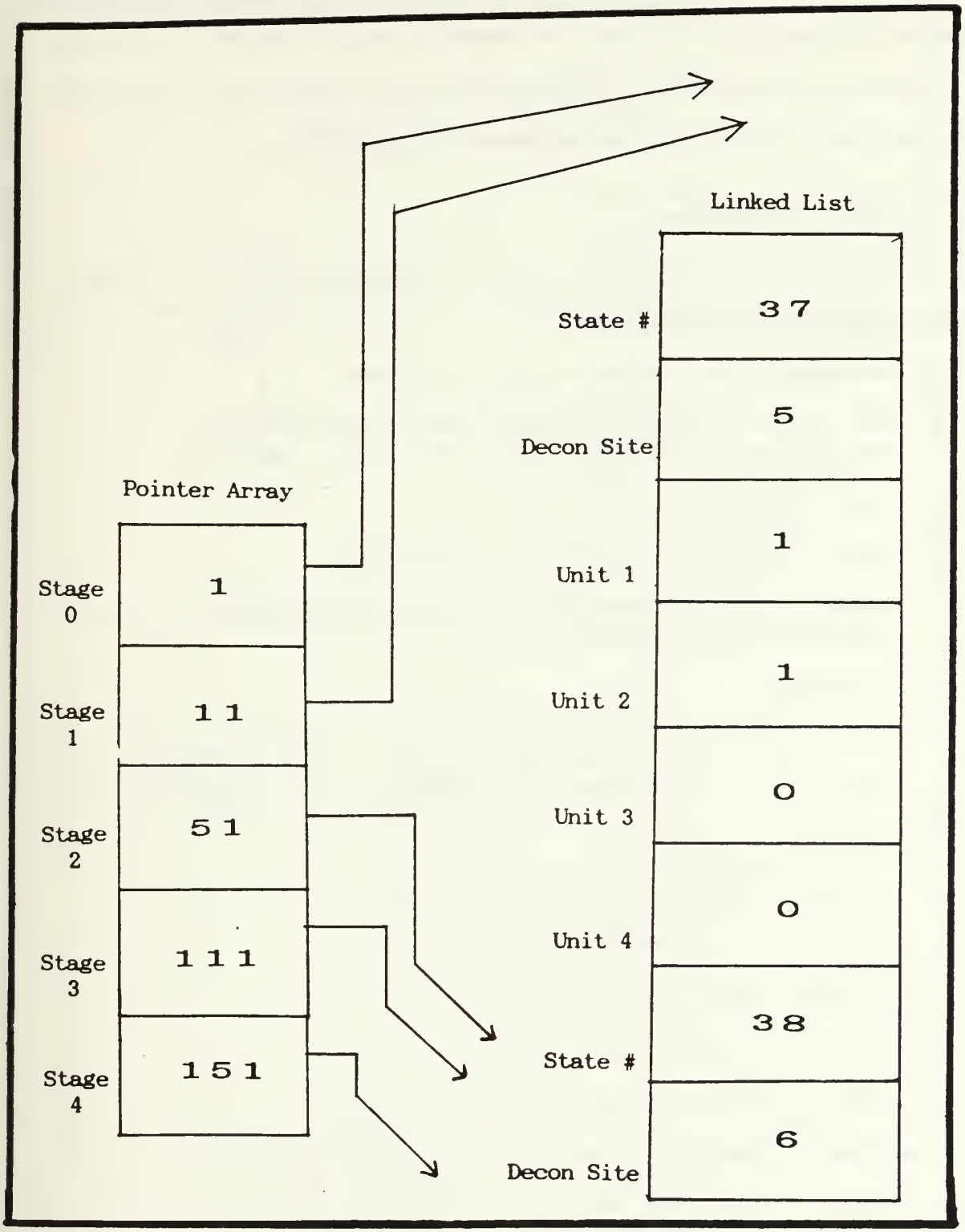
Another abstract data type that proved very useful is the Linked List. Each state in the DP graph requires the following attributes be assigned to it.

- State number
- Location of decon team (decon site number)
- Which units currently require decon

The first two items are integers identifying the state or site number. The status of each unit is a boolean argument; one for "needs decon" and zero for "already done" (see Figure 2.8).

In addition to the linked list of attributes, there is also a pointer array for the start of each stage. Since the number of states in each stage is known, the pointer array points to the start of that stage and the model sweeps the correct number of states through the stage. The boolean arguments are compared between the present or "from" state to the future or "to" state. From this comparison, two things are accomplished. First, it is determined if it is possible to reach this future state from the particular present state. For example, it is impossible to have units A and B left to decon and then go to a state with unit C left to decon.

Second, given that the future state does not contradict the present state, the model determines which unit undergoes decon. The future decon site location will dictate where the decon takes place. Given the information from the linked list, the decon time for the desired



Linked List Representation

Figure 2.8

"arc" in the DP graph can now be calculated. The travel times are tabled in a matrix. The time for decon is computed based on the number of vehicles in the unit (with three different vehicle types considered). A flow chart of the algorithm is shown in Figure 2.9.

H. INPUT PARAMETERS

The following is a summary of all factors considered in the model.

Decon Time Parameters:

- Base case decon time per vehicle (in hours)
- Time factors to adjust base case time for each vehicle type (with some reference vehicle as 1.0)
- Site attribute index
- Number of each type of vehicle in each unit
- Number of units that the decon team can process before requiring additional water.

GVS Parameters:

- ABIP's and BIP's for each unit
- Percent of unit BIP to use as threshold
- Degradation due to MOPP
- Attrition due to agent effects (unit specific)
- Ready time for units (when BIP is attained)
- NBC attack time
- When attrition will start
- Length of planning horizon

Map and Travel Time Attributes:

- Edge list (FROM NODE, TO NODE)

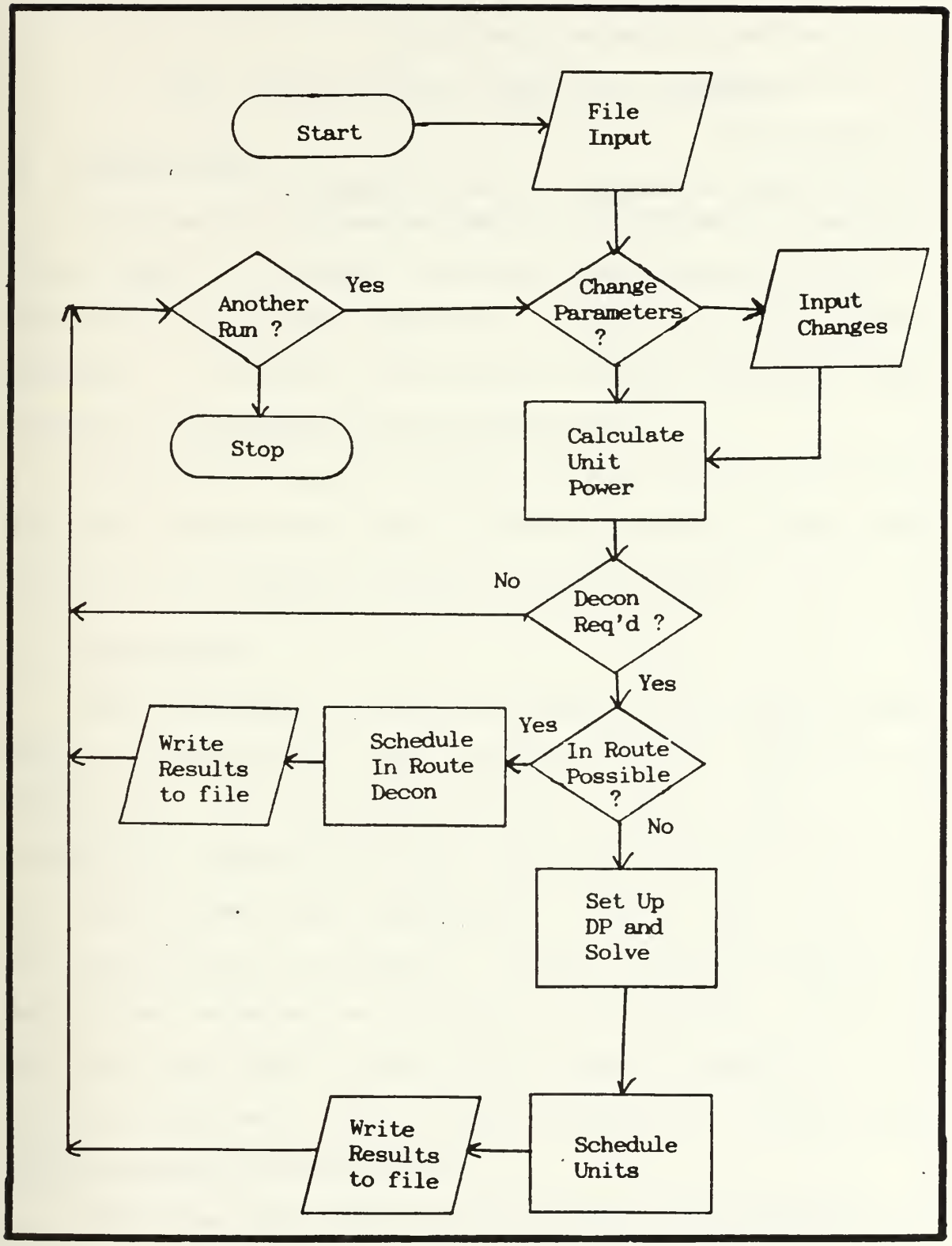


Figure 2.9 Flow Chart

- Arc distance (in kilometers)
- Arc trafficability factors (from 0 to 1)
- Site locations
- Unit locations
- Site closest to aggregate unit point of departure.

III. EXAMPLE RUN OF BASE CASE SCENARIO

A. INTRODUCTION

In this section the base case scenario is introduced and each step of the program is described. The network map being used, along with unit and site locations, are shown in Figure 2.2. As mentioned previously, it consists of 34 nodes and 72 arcs. The map itself represents a ten kilometer by ten kilometer area.

There are four units and ten decon sites. Each unit can contain any number of three vehicle types; truck, heavy truck, or track. There are a total of 40 vehicles in each unit for this scenario.

B. INPUT/OUTPUT

Input to the model is accomplished through file and terminal input. There are four files for input: MAP.DAT, UNITS.DAT, SITES.DAT, and GENERAL.DAT. The map file contains all edges, distances, and trafficability indices for the map. The units file contains all the unit locations and vehicle compositions. The site file contains all site locations and site attributes. The general data file contains all miscellaneous parameters not provided by terminal input. The source code listing for format of input files is given in Appendix A. The contents of the input files is shown in Appendix D. The file input remains constant throughout each run.

The terminal input allows the user to adjust certain parameters for each run. A default set of parameters is initially set by the model.

The user may change any of these. Tables 3.1 and 3.2 show the terminal input parameters for the base case scenario.

TABLE 3.1
Terminal Input

Input Parameter	Base Case Value
Unit Ready Time (hours from start)	1.0
NBC Attack Time (hours from start)	2.0
Time When Attrition Starts	8.0
Aggregate Unit Move Time	NONE
Planning Horizon (hours)	48.0
Power Threshold as % BIP	50%
Degradation Rate	0.02

TABLE 3.2
Unit Power Attributes

Unit	BIP	Attrition Rate (ATT(i))
1	1200	0.01
2	1100	0.02
3	1000	0.03
4	900	0.04

As many runs as desired may be made changing any of the above parameters. In the next chapter, variations of the degradation, attrition, and fraction of decon time realized are investigated. For this example, only the base case is shown. All input is echoed to an output file along with the results (file name is DECON.OUT). The entire output for the base case scenario is reproduced in Appendix B. The file input parameters (less the network map) are shown in Tables 3.3a through 3.3c. The model includes in the output a table of travel times between decon sites and units (see Table 3.4).

TABLE 3.3a
File Input
Location of Decon Sites

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000
Location of decon team is decon site: 10		

TABLE 3.3b
File Input (continued)
Location of Units, Misc. Parameters

Unit#	Node	Trks	Hvy Trks	Tracks
1	8	20	10	10
2	1	5	5	30
3	18	20	20	0
4	31	10	10	20

Aggregate unit anticipated
point of departure near site: 8
Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

TABLE 3.3c
File Input (continued)
Unit ABIP's, Decon Parameters

Unit #	Initial ABIP
1	500.00
2	400.00
3	300.00
4	350.00

Decon Time Index for Truck:	1.00
Decon Time Index for Hvy Truck:	1.20
Decon Time Index for Track:	1.50
Maximum Restoration from Decon:	80%
Number Missions Possible Before Requiring Water Resupply:	3

TABLE 3.4
Distance Table
(Time in hours required to reach sites)

	Site									
From/To	1	2	3	4	5	6	7	8	9	10
Site 1	.00	.07	.37	.18	.66	.60	.14	.22	.22	.34
2	.07	.00	.30	.11	.59	.53	.07	.15	.16	.27
3	.37	.30	.00	.26	.74	.76	.30	.38	.39	.51
4	.18	.11	.26	.00	.48	.50	.04	.12	.13	.25
5	.66	.59	.74	.48	.00	.19	.52	.60	.43	.32
6	.60	.53	.76	.50	.19	.00	.46	.48	.37	.32
7	.14	.07	.30	.04	.52	.46	.00	.08	.09	.20
8	.22	.15	.38	.12	.60	.48	.08	.00	.17	.28
9	.22	.16	.39	.13	.43	.37	.09	.17	.00	.11
10	.34	.27	51	.25	.32	.32	.20	.28	.11	.00
Unit	Site									
1	.70	.63	.82	.56	.09	.10	.56	.58	.47	.41
2	.64	.57	.81	.55	.14	.04	.50	.52	.42	.37
3	.70	.63	.52	.52	.44	.46	.56	.64	.65	.76
4	.10	.14	.44	.25	.73	.66	.20	.28	.29	.41

In this scenario, the aggregate unit will remain in the same area of operations for the entire planning window. All units have a different mix of a total of 40 vehicles each. The BIP for each unit varies as does the NBC attrition rates (e.g. some units are more susceptible to NBC agents than others). The degradation rate for all

units, however, is fixed. The decon team also requires water resupply after three missions.

Since the aggregate unit is stationary, the in-route decon option is not possible. The powers of each unit are computed over the planning window. Once the need for decontamination is established, the dynamic program is invoked. The results for the base case scenario are shown in Tables 3.5a through 3.5d.

TABLE 3.5a
Preparation Coefficient (B(i))
(see Eqn 2.1)

Unit 1 Preparation Coeff =	0.8755
Unit 2 Preparation Coeff =	1.0116
Unit 3 Preparation Coeff =	1.2040
Unit 4 Preparation Coeff =	0.9445

TABLE 3.5b
Unit Power

Unit	Threshold Power	Power at Hour 48 w/o Decon
1	600	320.56
2	550	196.97
3	500	120.03
4	450	72.41

TABLE 3.5c
Decontamination Scheme

Unit	Start Time	Move Time	Decon Time	Final Move	Finish	Site
4	13.46	0.20	2.60	0.20	16.46	7
3	16.46	0.46	2.20	0.46	19.58	6
1	19.58	0.25	2.35	0.10	22.28	6
2	22.28	0.04	2.80	0.04	25.17	6
Total time used (in hours) for decon operations is: 11.71						

TABLE 3.5d
Restored Power and
Restoration Coefficient (R(i))
(see Eqn 2.5)

Unit 1	Final Power =	1109.25; Restore Coeff =	0.1687
Unit 2	Final Power =	990.00; Restore Coeff =	0.2099
Unit 3	Final Power =	913.53; Restore Coeff =	0.2163
Unit 4	Final Power =	833.67; Restore Coeff =	0.1474

C. DISCUSSION OF RESULTS

The power plots for each unit are shown in Figures 3.1 through 3.4. The plots indicate the unit power throughout the planning window. Each plot shows four distinct phases. The first phase is the unit starting from its ABIP and realizing its BIP. All units attain BIP at hour one. This corresponds to the required ready time. The unit BIPs are constant up until the NBC attack at hour two. Starting at hour two, the curve has an inflection (phase two). This is from power loss due to performance degradation realized from being in a chemical protective posture. At hour eight (phase three), the inflection becomes steeper. At this point, the units are not only being degraded but undergoing an additive attrition effect as well.

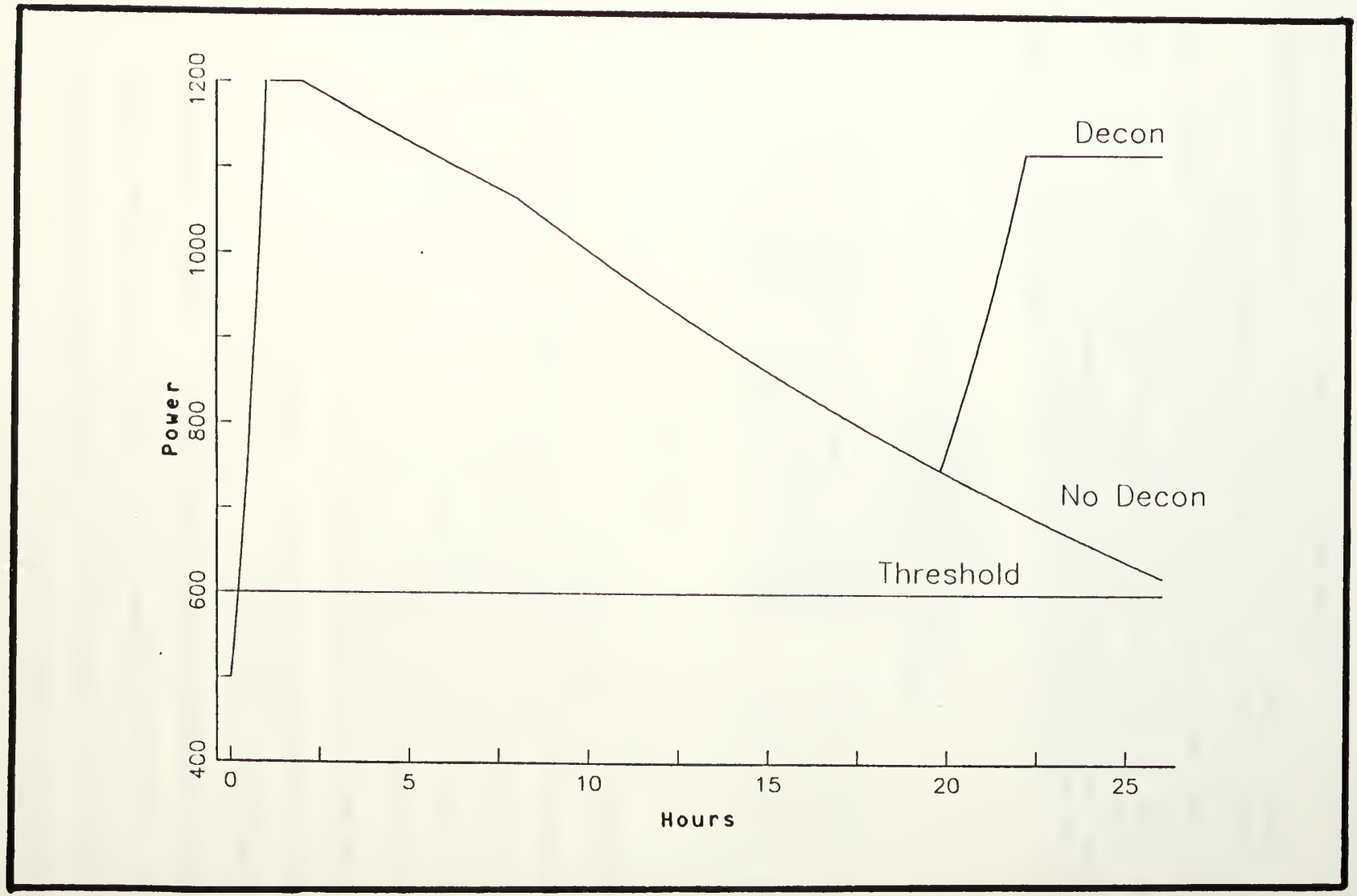


Figure 3.1 Unit One Power Plot

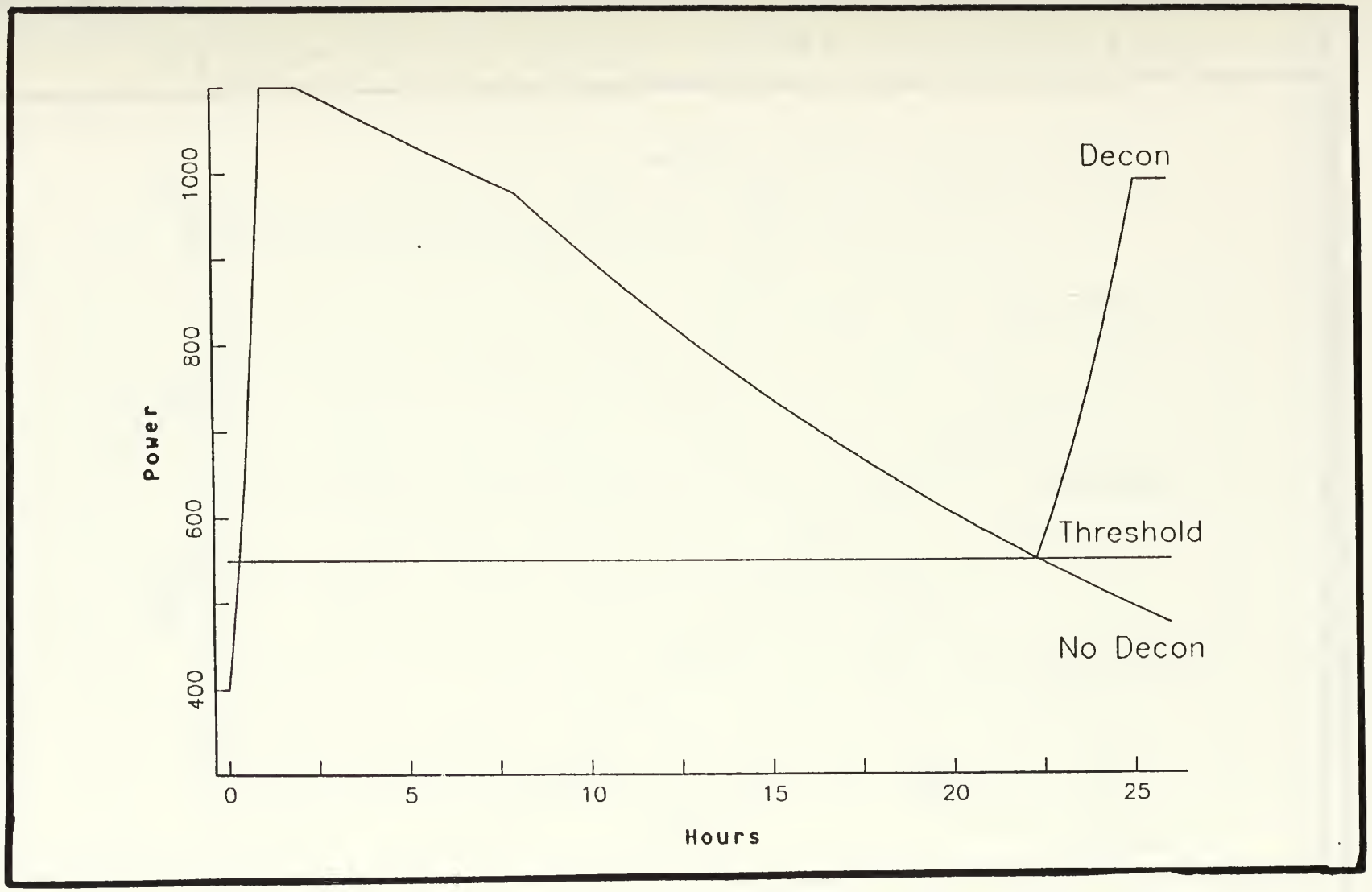


Figure 3.2 Unit Two Power Plot

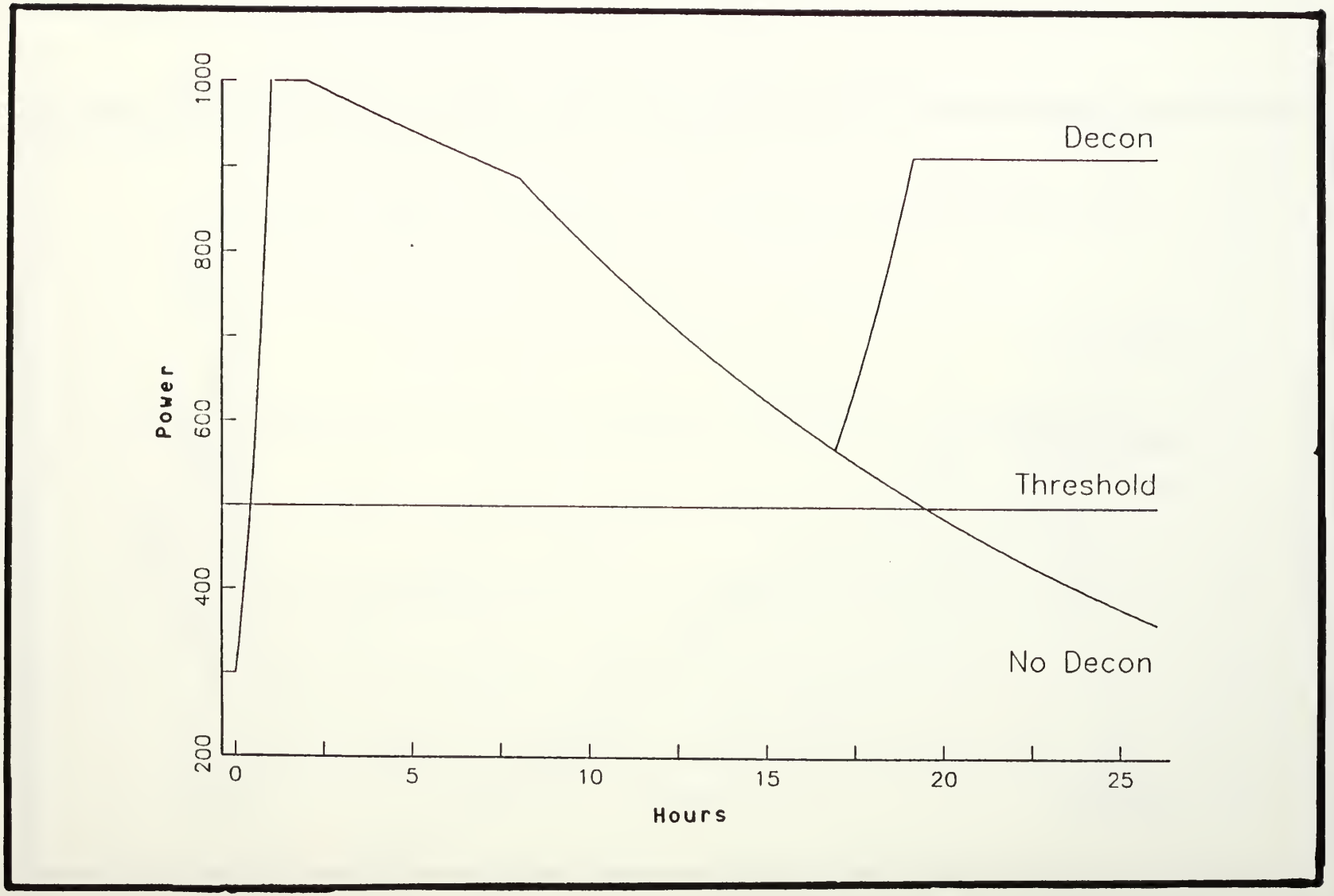


Figure 3.3 Unit Three Power Plot

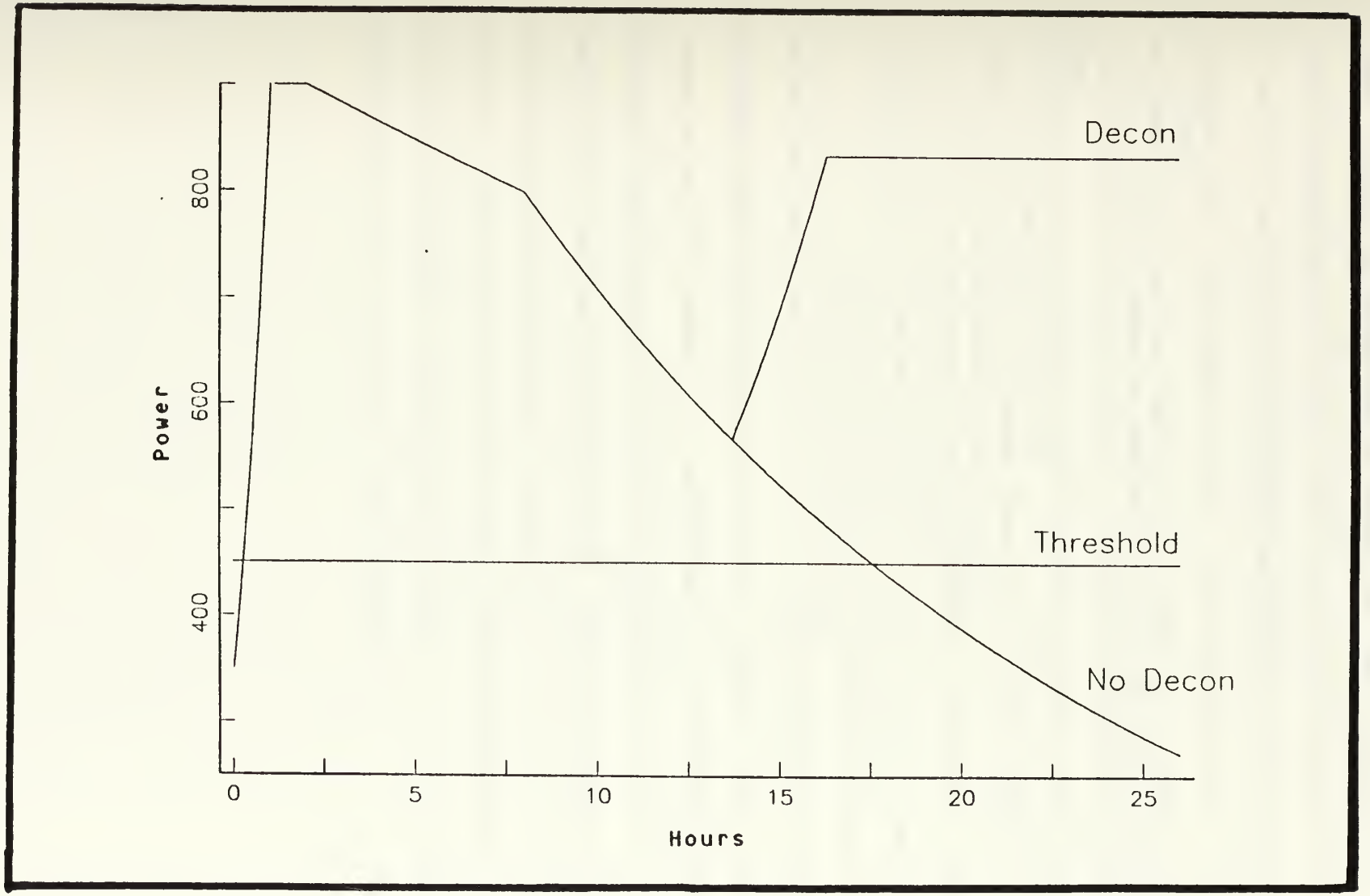


Figure 3.4 Unit Four Power Plot

Finally (phase four), the units undergo decon at various times. The curve rises from the current level to 80% *of the difference* between the pre-decon power and BIP (see Eqn 2.5). The interval of time in which this occurs is the decon time for that unit. The decision algorithm produces the fastest decon scheme and the latest possible start time to implement the scheme. Note that unit two is the critical unit. That is, unit two undergoes decon precisely at its threshold time. A careful look at unit two's power plot (Figure 3.2) clearly illustrates this point. Delaying the decon operation would cause unit two to become infeasible before any of the other units. This is despite the fact that unit four has the largest attrition rate.

Another important factor is the total time used for decon operations, shown in Table 3.5c as 11.71 hours. This means that the decon team spent 11.71 hours performing its mission. It does not mean that all units were occupied for 11.71 hours. Each unit spent less than three hours undergoing decon. Even though the attack occurred at time 2.0, the first decon does not start until time 13.46. This means that unit four may perform its individual mission up to time 13.46, at which time it must be at its designated unit position. Likewise, the other units must be at their designated unit locations no later than their scheduled move out times.

IV. SENSITIVITY ANALYSIS

A. ISSUES

There are five areas of concern that will be addressed in this chapter:

- Verification of the Algorithm
- Sensitivity to degradation rate changes
- Sensitivity to attrition rate changes
- Sensitivity to partial decon times
- Scenario with six units and two decon teams.

B. MODEL VERIFICATION

A simple test was devised to verify the dynamic program algorithm. Two remote decon sites were given site attributes of 0.3 (i.e., giving reduced decon times). The model was then run to determine if the DP would force the decon operations to these sites. Decon sites nine and three were chosen (see Figure 2.2). These sites take more time to reach than some of the others, especially site three. Table 4.1 shows the results.

TABLE 4.1
Verification Run Results
Decontamination Scheme

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
1	16.90	0.47	0.18	0.47	18.02	9
4	18.02	0.29	0.20	0.29	18.79	9
3	18.79	0.67	0.17	0.52	20.15	3
2	20.15	0.42	0.21	0.42	21.19	9
Total time used (in hours) for decon operations is:						4.29

The model reacted as expected to the new input data. All decon was routed to sites three and nine. Approximately two hours per unit were saved. This allowed for travel to any location on the network map. The solution choice for what unit is assigned to which site does yield the closer site (see Table 3.4). Site three is close to unit three. The other units are better off at site nine.

C. SENSITIVITY TO ATTRITION AND DEGRADATION COEFFICIENTS

Unit two is the critical unit since it violates its threshold before the other units. Therefore, the decon schedule is such that unit two undergoes decon at its threshold time. Although unit two does not have the highest rate of power loss, it will reach its threshold because (in this case) it is the last unit to receive decontamination.

Since unit two is the most interesting case, it will be discussed in greater detail. All units will be investigated for attrition and degradation coefficients that violate their thresholds. A sensitivity analysis will also be performed to investigate the amount of change associated with a given change in these parameters.

Each unit may be assigned a unique attrition rate. Conversely, the degradation rate is a global value and effects all units simultaneously. For the purposes of this investigation, all unit parameters will be held at their base case value while the parameter in question is investigated.

Three runs were made for varied attrition coefficients and degradation coefficients for unit two. These six runs were plotted and are displayed in Figures 4.1 thru 4.6, indicating the break point for unit two in each case.

Since the earliest time of decon for unit two is 10.87, any parameter that causes unit two to hit its threshold before this time will create an infeasibility. The critical attrition rate for unit two was found to be 0.1797 and the critical degradation rate was 0.07167. Any value greater than these will force unit two below its threshold before it can undergo decon.

The critical values for unit two were found by solving the power equations given in Chapter 2. The model results are summarized in Tables 4.2 and 4.3.

TABLE 4.2
Unit Two Attrition Break Point

RUN	Att Coeff	Threshold Time	Earliest Decon Start	Actual Decon Start	Restored Power
1	.2000	10.61	10.87	10.87	984
2	.1797	10.87	10.87	10.87	990
3	.1600	11.18	10.87	11.18	990

(Base Case Restored power: 990.00)
(Base Case Decon Start: 22.33)
(Base Case ATT = 0.02)
(Base Case DEG = 0.02)

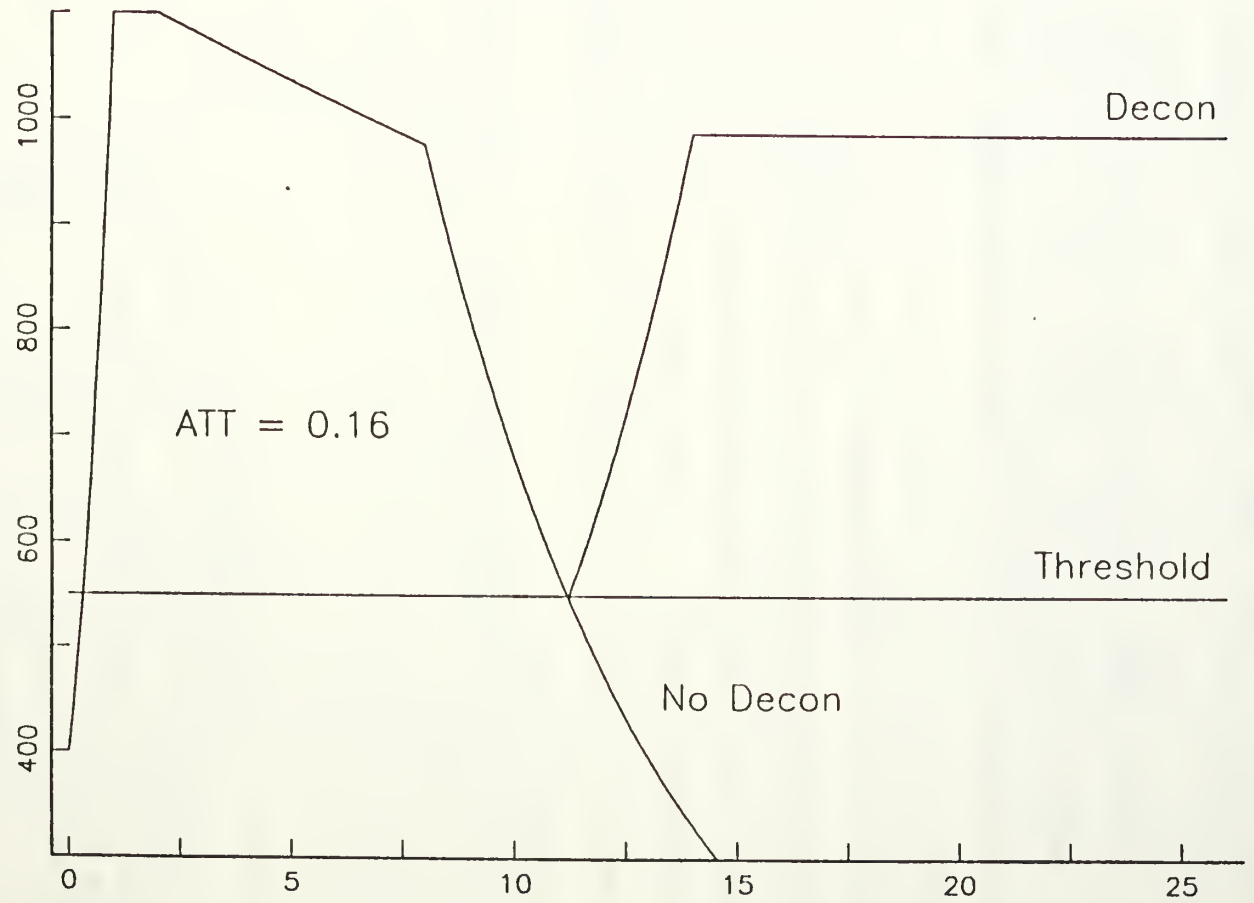


Figure 4.1 Unit Two Sensitivity Analysis; ATT=0.16

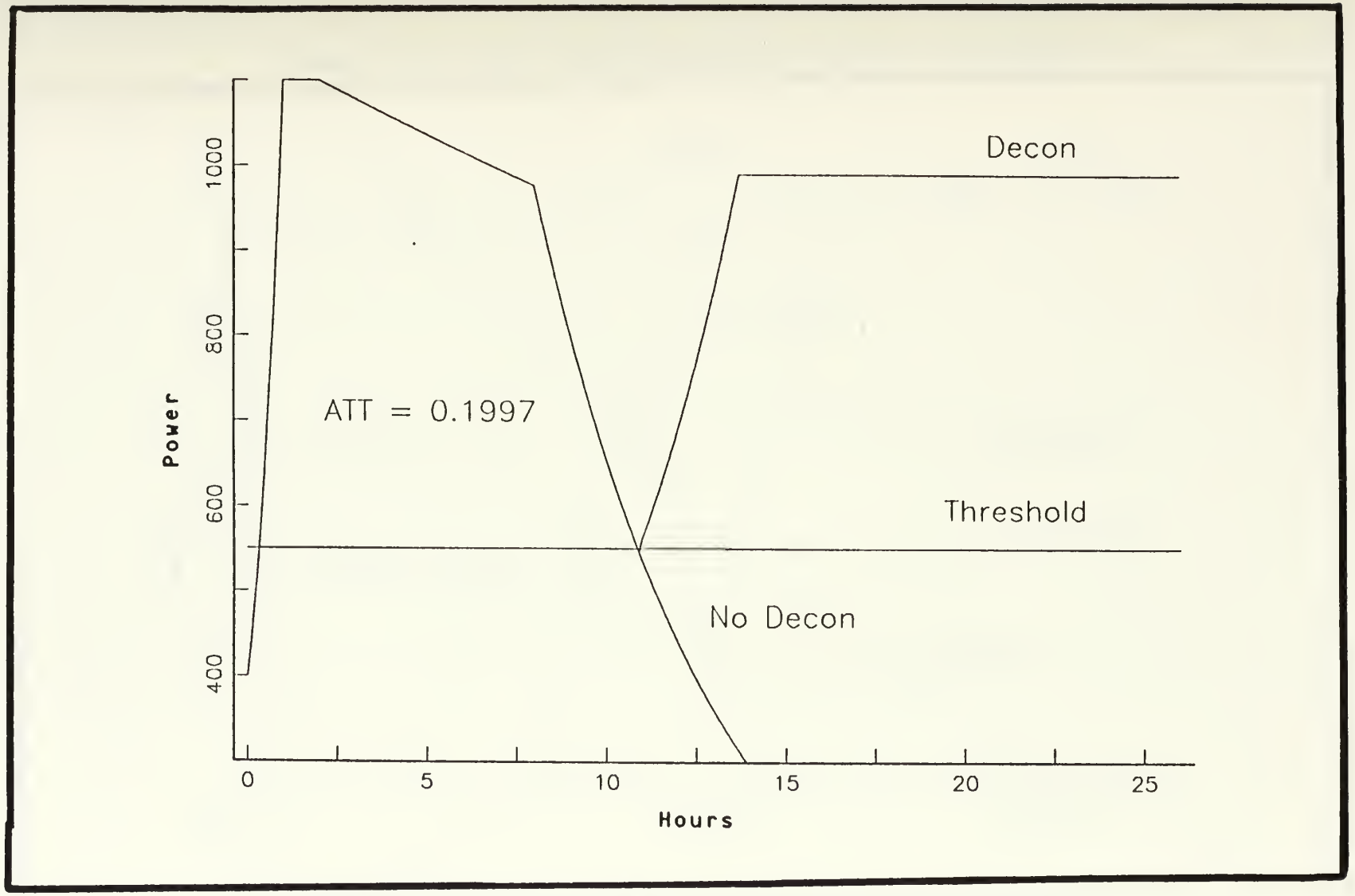


Figure 4.2 Unit Two Sensitivity Analysis; ATT=1997

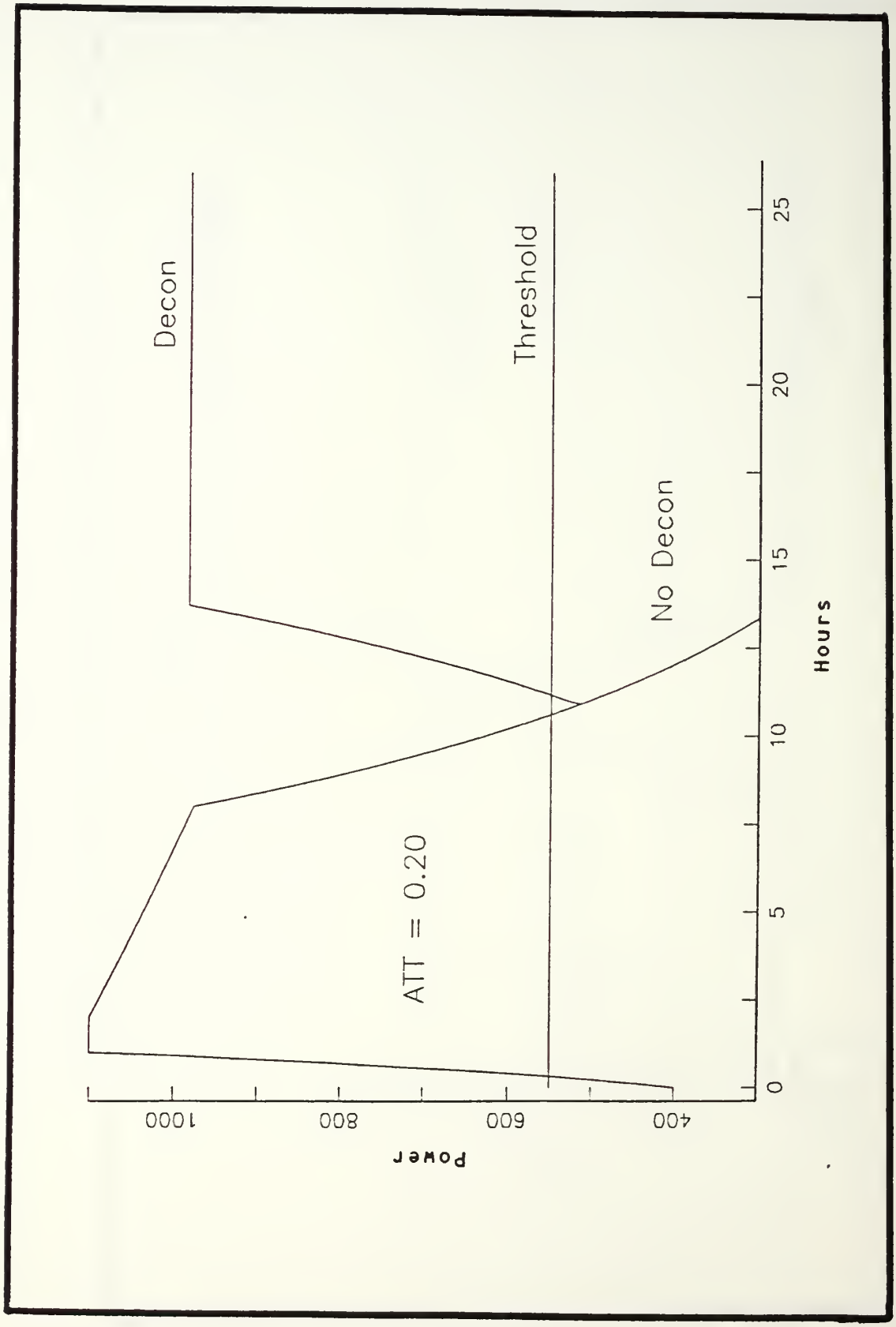


Figure 4.3 Unit Two Sensitivity Analysis; ATT=0.20

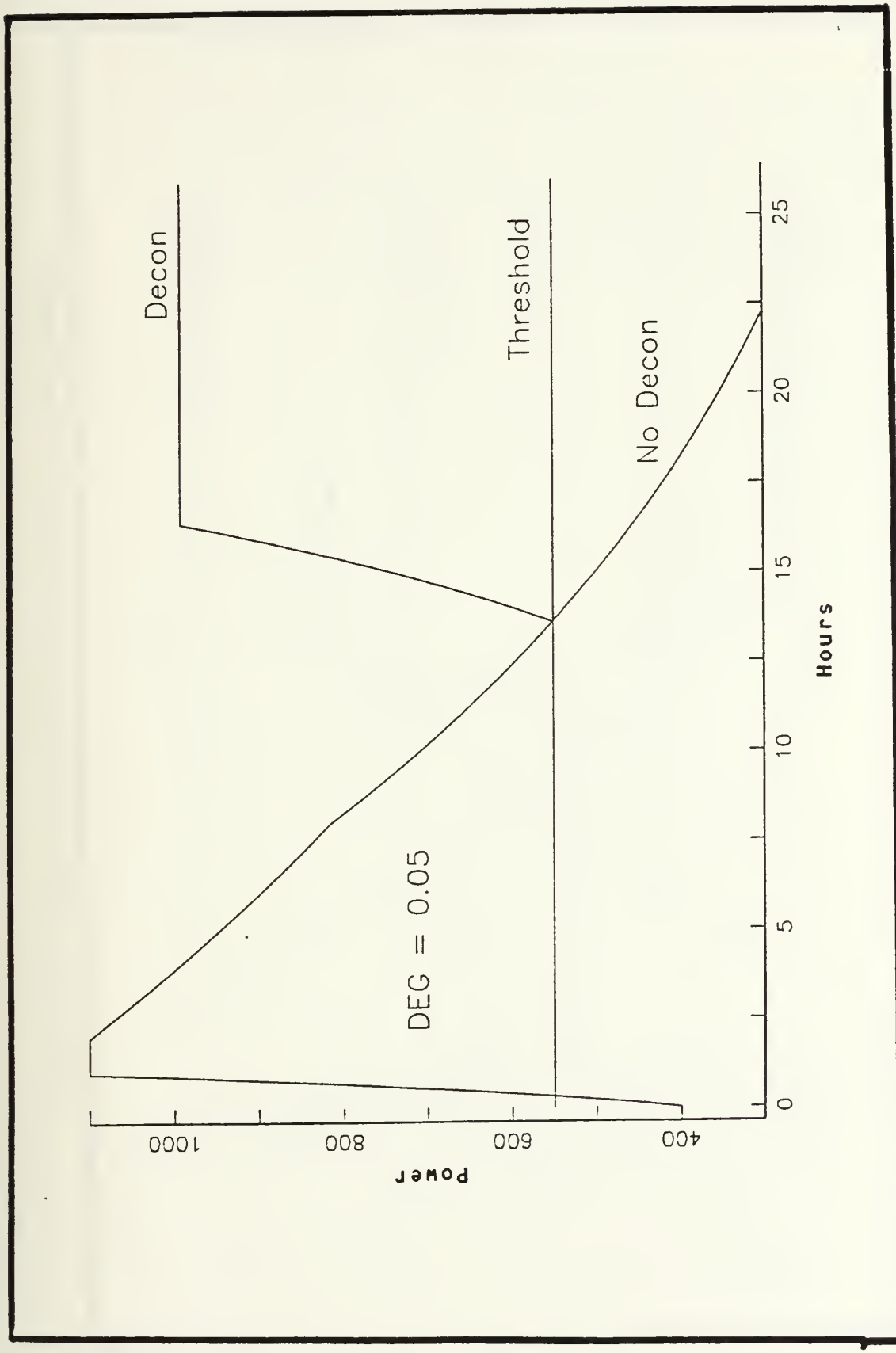


Figure 4.4 Unit Two Sensitivity Analysis; DEG=0.05

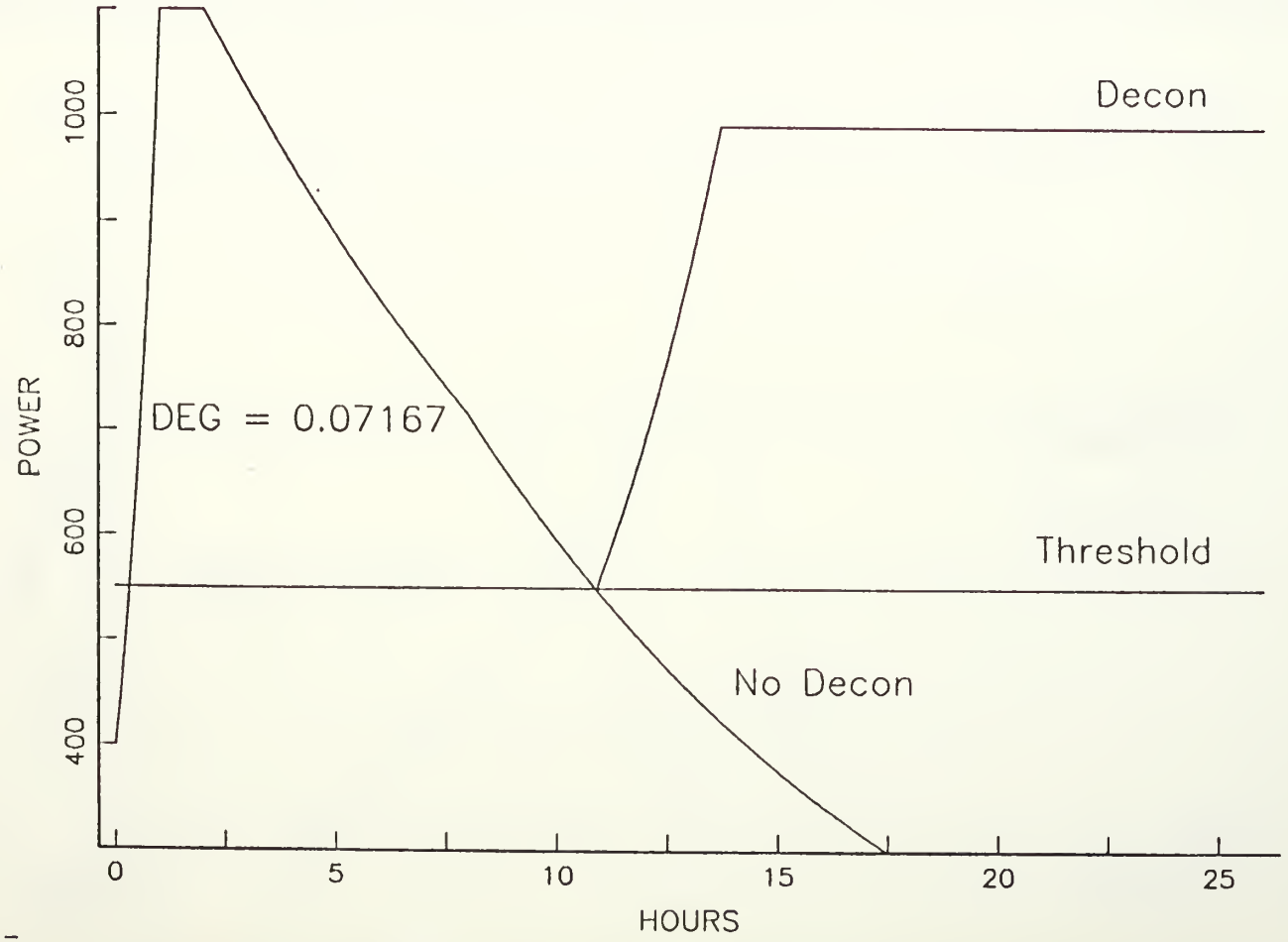


Figure 4.5 Unit Two Sensitivity Analysis; DEG=0.07167

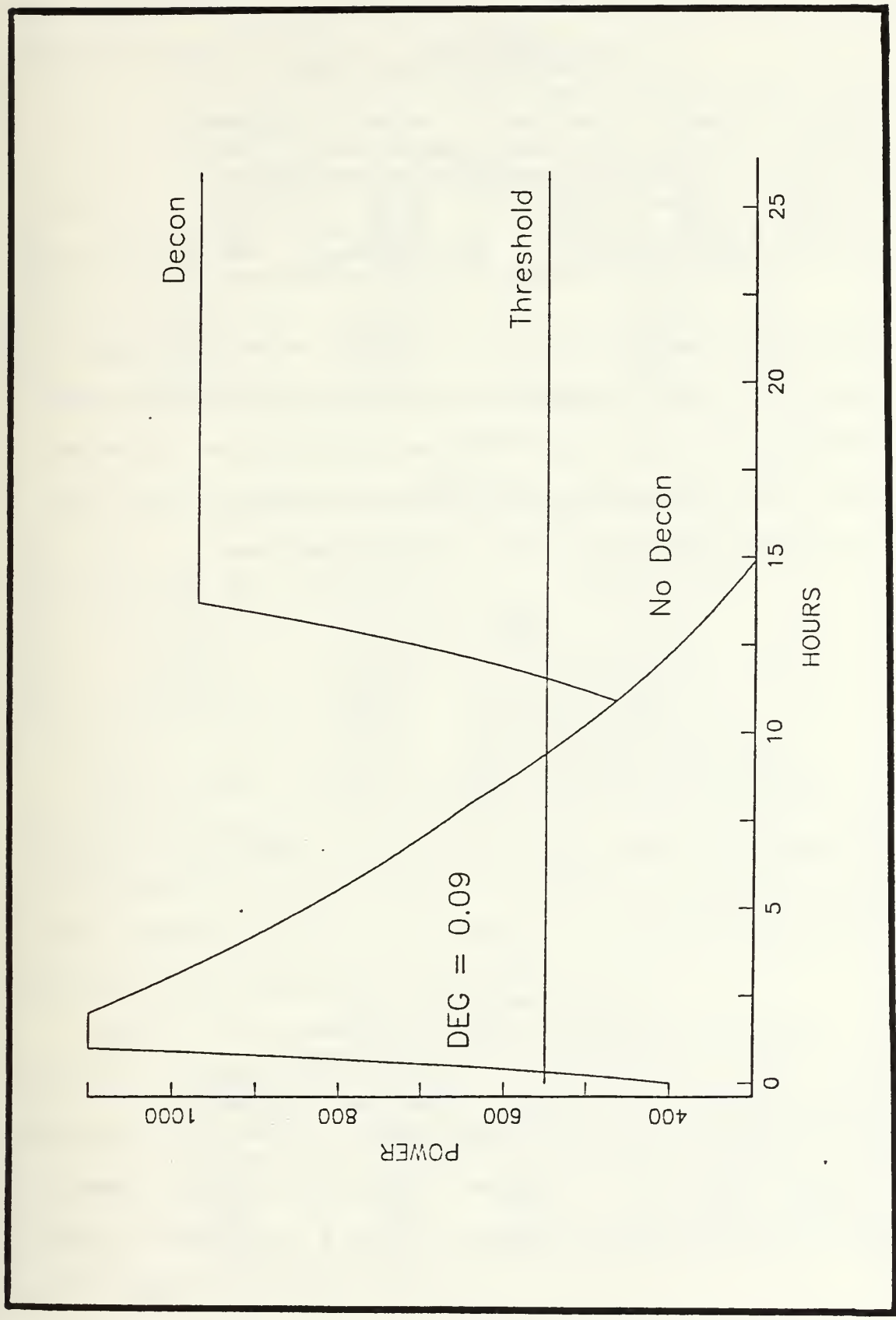


Figure 4.6 Unit Two Sensitivity Analysis; DEG=0.09

TABLE 4.3
Unit Two Degradation Break Point

RUN	Deg Coeff	Threshold Time	Earliest Decon Start	Actual Decon Start	Restored Power
1	.0900	9.39	10.87	10.87	973
2	.0717	10.87	10.87	10.87	990
3	.0200	13.62	10.87	13.62	990

The attrition break points (i.e., threshold values) only apply to units one and two. This is because the earliest decon times allow units three and four to undergo decon before enduring attrition. Therefore, these units will not have break points associated with attrition rates. Table 4.4 summarizes the break point results for unit one.

TABLE 4.4
Unit One Attrition Break Point

Attrition Break Point:	1.4883
Threshold Time:	8.38
Base Case Restored Power:	1109
Critical Restored Power:	1080

The degradation break points for units one, three, and four are summarized in Table 4.5.

TABLE 4.5
Degradation Break Points
for Units One, Three, and Four

Unit	Critical DEG	Threshold Time	Earliest Decon Start	Critical Restored Power	Base Case Restored Power
1	.108	8.38	8.38	1080	1109
3	.1998	5.47	5.47	900	914
4	3.4657	2.20	2.20	810	834

The sensitivity data associated with doubling the attrition and degradation rates are given in Tables 4.6 and 4.7.

TABLE 4.6
Sensitivity of Attrition Coefficient

Unit	% Change ATT	% Change Threshold time	% Change Restored Power
1	+100.00	-21.36	-1.50
2	+100.00	-21.41	0.00
3	+100.00	-22.10	-2.92
4	+100.00	-21.77	-2.76

TABLE 4.7
Sensitivity of Degradation Coefficient

Unit	% Change DEG	% Change Threshold time	% Change Restored Power
1	+100.00	-37.05	-0.23
2	+100.00	-43.10	0.00
3	+100.00	-26.64	+2.35
4	+100.00	-22.17	+4.12

Note from Table 4.6 that although unit two has zero change in its power with an increase in rate of attrition, it forces decon operations to start earlier in order to maintain feasibility (time 8.68 versus time 13.46). Changing the attrition parameter for the other units does not effect the start decon time.

Likewise, similar results occur with the degradation rate variations in Table 4.7. Doubling the degradation actually increases the restored power of units three and four! This is because the model is forced to start decon earlier resulting in less power loss, with the trade-off being time. With the increased degradation value, the start time is moved from 13.46 to 6.68.

D. SENSITIVITY TO FRACTION OF DECON TIME REALIZED

Figure 4.7 shows graphically the results of reducing the decon time. Table 4.8 summarizes the effect of using only 50% of the required decon time.

TABLE 4.8
Sensitivity Associated with
Partial Decon Times

Unit	Restored Power w/ Full Time	50 % Time	% Change in Restored Power
1	1109.25	891.83	-19.60
2	990.00	737.90	-25.47
3	913.53	675.75	-26.03
4	833.67	610.13	-26.68

E. DUAL DECON TEAM SCENARIO

The model can also be used for a multi-decon team problem as described in this section. Three runs consisting of six units and two decon teams were made (see Figures 4.8 and 4.9). The first run had one decon team at site 10. The other two split the units into two groups of three with one decon team at site 10, and the other at site 7. The two small runs were then combined, and the results are shown in Tables 4.9 and 4.10.

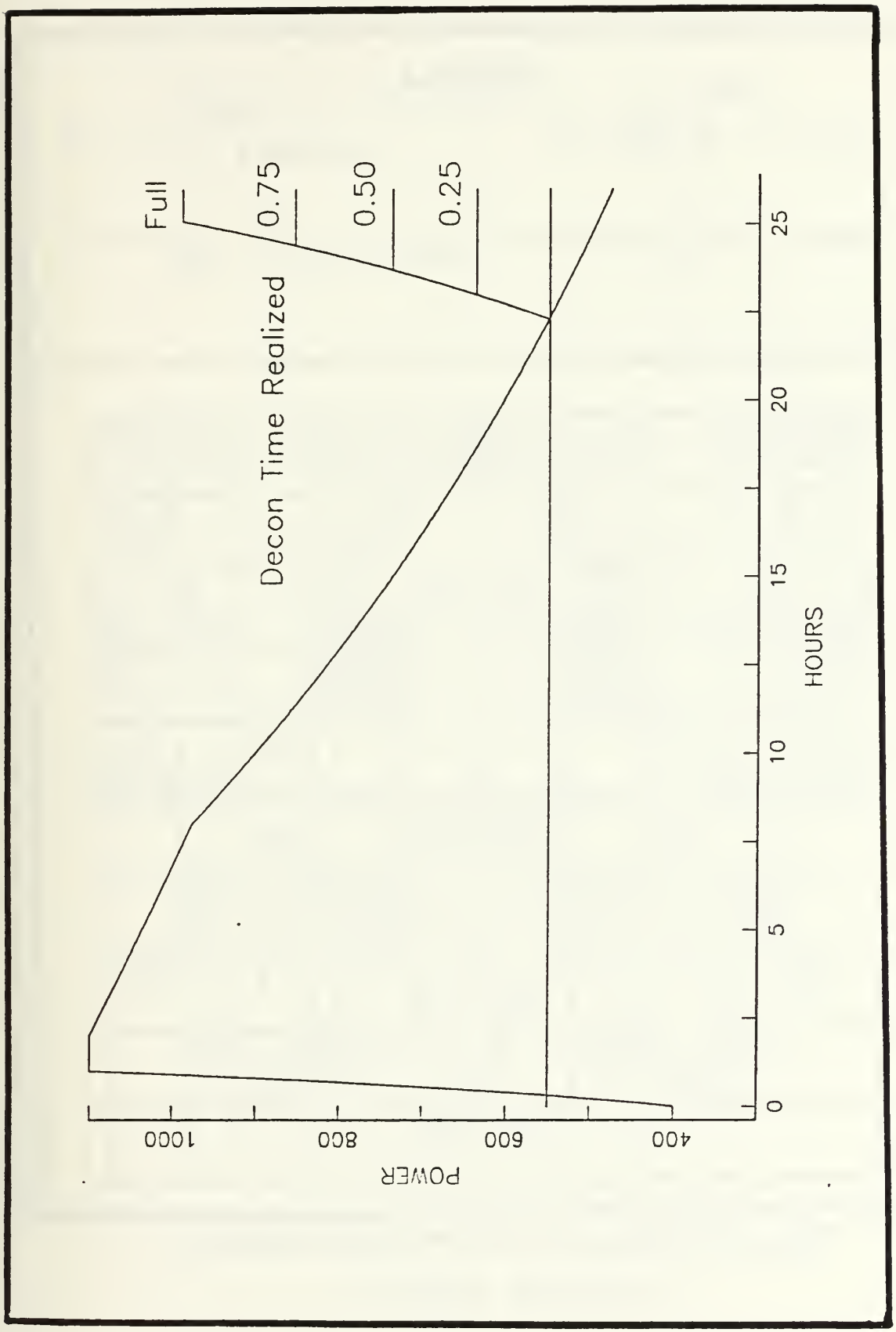
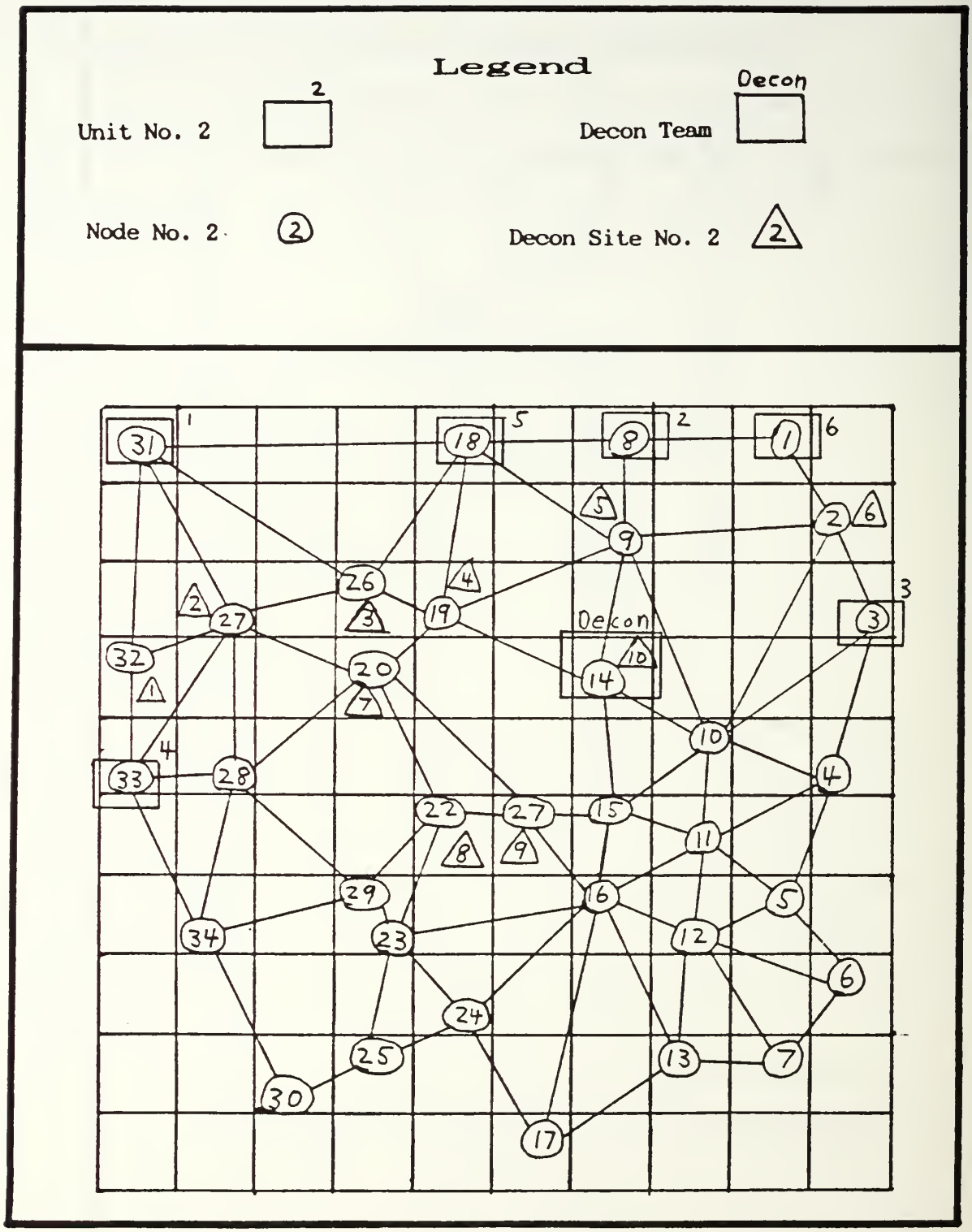
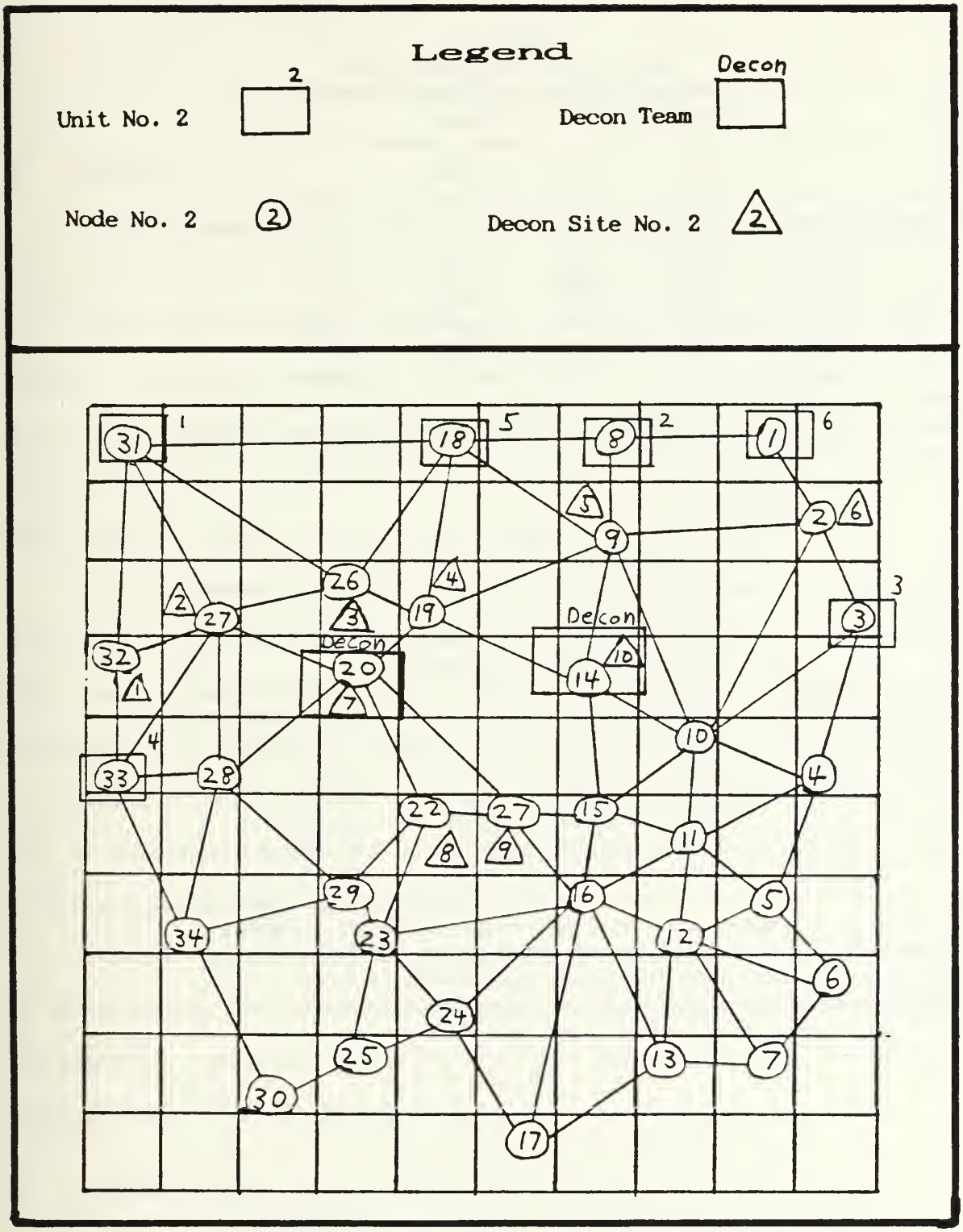


Figure 4.7 Unit Two; Fractions of Decon Time



Six Units, One Decon Team

Figure 4.8



Six Units, Two Decon Teams

Figure 4.9

TABLE 4.9
(Six Units, One Decon Team)

Decontamination Scheme						
Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
1	8.26	0.27	2.60	0.14	11.26	2
4	11.26	0.09	2.47	0.09	13.90	1
5	13.90	0.75	2.20	0.46	17.31	6
6	17.31	0.04	2.80	0.04	20.20	6
3	20.20	0.08	1.72	0.08	22.08	6
2	22.08	0.25	2.35	0.10	24.78	6
Total time used (in hours) for decon operations is: 16.52						

TABLE 4.10
(Six Units, Two Decon Teams)

Decontamination Scheme						
Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	10.05	0.14	2.47	0.09	12.74	1
5	12.74	0.60	2.20	0.46	15.99	6
1	14.55	0.20	1.95	0.20	16.91	7
6	15.99	0.19	2.80	0.04	19.03	6
2	16.91	0.46	1.76	0.10	19.23	6
3	19.23	0.23	1.29	0.08	20.83	6
Decon team 1 starts at site 7 and supports units 1 thru 3 Decon team 2 starts at site 10 and supports units 4 thru 6 Team 1 total time used for decon operations is 6.28 Team 2 total time used for decon operations is 8.98						

V. SUMMARY/FUTURE DIRECTIONS

A. SUMMARY

The NBC decon decision model is a stand alone, PC based FORTRAN model used for scheduling a collection of units for NBC decontamination. It utilizes the principles of the Generalized Value System, along with a dynamic programming technique to produce an optimal decision. The decision is optimal in that the time for decon for all units is the shortest possible and starts at the latest allowable time for each unit. The times are constrained by a user defined threshold of unit power.

With this model, it is possible to determine how much flexibility one has in a given tactical situation. The look-ahead feature of the GVS incorporated in the model allows for a more realistic representation of NBC decon operations. Current decisions can be made based on future projections of unit power. The model represents a collection of units with a specified number of three vehicle types in each unit, thus implying a particular organizational unit.

Although the model is primarily concerned with hasty decontamination, deliberate decontamination may also be represented. Additionally, scenarios involving multiple decon teams may be solved using multiple runs of the model.

B. FUTURE DIRECTIONS

There are many possible enhancements for this model. One would be better representation of deliberate decon operations. This could be

accomplished by providing another routine that specifically computes deliberate decon times. The routine would require personnel data for each unit, as well as site attributes and logistical constraints. The DP recursion may in this case be used to minimize the amount of logistics used in large scale decontamination.

The current model minimizes the total decon operation time for the optimal solution. Other decision criteria may be used. These include minimizing the spread of contamination, or providing priority to certain unit types for a given mission.

Another possible enhancement to the model would allow multiple decon team problems in one run. However, this would create a problem with what to do about sites being used simultaneously. In the current application, this problem is simply ignored since small scale hasty decon operations can be done concurrently on the same site. For larger deliberate decon operations, no sharing of decon sites should be allowed.

In addition to modelling enhancements, further work is required for more reliable input data. The data collection efforts done so far are either obsolete or non-existent in the area of decontamination times.

Another important consideration is reliability data for the decon equipment. Decon equipment (especially the older types) would probably not operate reliability for 11 hours. It is the experience of the author that at least one or two backups would be required for any reasonable level of confidence under those conditions.

Another related topic would be to set up a queuing model for deliberate decontamination operations. This high resolution approach

would allow investigation of the current doctrine for deliberate decon. From this work it may be possible to make the deliberate decon operation more efficient. Perhaps different setups could be tailored for specific situations where arrival rates are known. The impact of decon equipment reliability could also be assessed.

Hasty decon operations should not be down played or over-simplified. With the exception of fixed installations, many units may not receive enough contamination to justify a deliberate decon operation. Weathering effects may diminish much of the agent effects, depending on the type of agent involved. Highly mobile combat units on the modern battlefield will have little time for a full scale deliberate decontamination. Hasty decontamination operations will therefore have a dominant role in most land combat model scenarios.

APPENDIX A
SOURCE CODE FOR MODEL

```
C**************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<<  MAIN PROGRAM  >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>**
C**************************************************************************
      PROGRAM DECON
C* * * * * Non-executable Statements * * * * * *
C* * PARAMETER data for array dimensions * *
      INTEGER MAXNODES,MAXUNITS,MAXARCS,MAXSITES,DSUM,LMAX,STMAX,SMAX
      PARAMETER(MAXNODES=36,MAXARCS=145,MAXUNITS=6,MAXSITES=10)
      PARAMETER(LMAX=5120,STMAX=640,SMAX=7,DSUM=16,JJ=3)
C* * Other PARAMETER info * *
      PARAMETER(DEFAC1=1.0,DEFAC2=1.2,DEFAC3=1.5,RESTMAX=.8)
      PARAMETER(DECR=0.25,ITER=1)
C* * * * * * * * * * * Variable Declaration follows * * * * * * * * * * *
      CHARACTER RESP*1
C* * INTEGER variables * *
      INTEGER EP(MAXNODES),HEAD(MAXARCS),SITE(MAXSITES)
      INTEGER UNIT(MAXUNITS),DTM,NUNITS,WATER,SP,RUN
      INTEGER PRED(MAXNODES),TRUCK(MAXUNITS),HTRUCK(MAXUNITS)
      INTEGER TRACK(MAXUNITS),INDEX(MAXUNITS),LLIST(LMAX)
      INTEGER DPHEAD(STMAX),STAGE(0:SMAX),VAR(MAXUNITS),TNODE(MAXUNITS)
      INTEGER HNODE(MAXUNITS),ORDER(STMAX),VFLAG(MAXUNITS)
C* * REAL variables * *
      REAL SIP(MAXUNITS),B(MAXUNITS),MTIME,ITEM(MAXUNITS),DPTOTAL(STMAX)
      REAL DIST(MAXARCS),D1(MAXNODES),D2(MAXNODES),VTIME(MAXUNITS)
      REAL ALPHA(MAXARCS),ATT(MAXUNITS),ABIP(MAXUNITS),CSIP(MAXUNITS)
      REAL DMAT(DSUM,MAXSITES),UTIME(STMAX,JJ),UDTIME(MAXUNITS)
      REAL FPOWER(MAXUNITS),EPOWER(MAXUNITS),SAT(MAXSITES)
      REAL ST(MAXUNITS),REST(MAXUNITS),FSIP(MAXUNITS),THRESH(MAXSITES)
C* * * * * * Open Output File * * * * * *
      OPEN(7,FILE='DECON.OUT')
      WRITE(7,10)
10    FORMAT(' Land Combat decision program for'/' NBC Decontamination O
     *perations.'//' CPT John C. Roberts'/' U.S. Navy Postgraduate Schoo
     *l'////16X,' <<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>
     *')
C* * * * * * Input Data from files * * * * * *
      DATA DIST/MAXARCS*0.0/,ALPHA/MAXARCS*1.0/
      CALL INPUT(EP,HEAD,DIST,NVERT,SITE,UNIT,DTM,NUNITS,NSITES,WATER,
     *SP,SPEED,ABIP,ETIME,HDTIME,TRUCK,HTRUCK,TRACK,ALPHA,SAT,DEG,
     *PERCENT,RTIME,ATIME,BMOVE,HORIZ,SIP,ATT)
C* * * * * * Initialize Program * * * * * * *
      DO 20 I=1,MAXARCS
            DIST(I)=DIST(I)/ALPHA(I)
20    CONTINUE
      RUN=0
```

```
      WRITE(7,30)DEFAC1,DEFAC2,DEFAC3
30    FORMAT(/' Decon time index for truck: ',F5.2/' Decon time index fo
     *r hvy truck: ',F5.2/' Decon time index for track: ',F5.2)
C* * * * * Compute decon time for each unit * * * * *
      DO 40 I=1,NUNITS
            R1=TRUCK(I)
            R2=HTRUCK(I)
            R3=TRACK(I)
            UDTIME(I)=HDTIME*((DEFAC1*R1)+(DEFAC2*R2)+(DEFAC3*R3))
40    CONTINUE
C* * * * * Build Distatnce Matrix form ea site/unit to ea site * * * * *
      DO 60 I=1,(MAX(NSITES,NUNITS))
            IF(I.LE.NSITES)CALL PATH(DIST,D1,EP,HEAD,PRED,NVERT,SITE(I
     *))
            IF(I.LE.NUNITS)CALL PATH(DIST,D2,EP,HEAD,PRED,NVERT,UNIT(I
     *))
            DO 50  J=1,NSITES
                 IF(I.LE.NSITES)DMAT(I,J)=D1(SITE(J))
                 IF(I.LE.NUNITS)DMAT((I+NSITES),J)=D2(SITE(J))
50          CONTINUE
60    CONTINUE
      DO 90 I=1,DSUM
            DO 80 J=1,NSITES
                 DMAT(I,J)=DMAT(I,J)/SPEED
80             CONTINUE
90    CONTINUE
C* * * * * Write distance matrix to output file * * * * *
      WRITE(7,100)
100   FORMAT(/27X,' Distance Table'/20X,' (Time required to reach sites)
     *')
      WRITE(7,110)NSITES
110   FORMAT(/'Sites\',22X,' Sites 1 to ',I2)
      DO 130 I=1,NSITES
            WRITE(7,120)I,(DMAT(I,J),J=1,NSITES)
120         FORMAT(' ',I2,1X,10F6.2)
130   CONTINUE
      WRITE(7,140)
140   FORMAT(' Units')
      DO 160 I=(NSITES+1),(NSITES+NUNITS)
            K=I-NSITES
            WRITE(7,150)K,(DMAT(I,J),J=1,NSITES)
150         FORMAT(' ',I2,1X,10F6.2)
160   CONTINUE
C* * * * * * Simulations loop follows * * * * * *
190   WRITE(6,200)
200   FORMAT(' Do you desire another run (enter <Y> or <N>)?'/)
      READ(5,'(A1)')RESP
      IF((RESP.EQ.'N').OR.(RESP.EQ.'n'))THEN
            CLOSE(UNIT=7,STATUS='KEEP')
            STOP
      ENDIF
      IF((RESP.NE.'Y').AND.(RESP.NE.'y')) GOTO 190
```

```
      RUN=RUN+1
      WRITE(7,210)RUN
      WRITE(6,210)RUN
210   FORMAT(/' ******** Run number ',I3,' **********'/)
C* * * * * *Terminal Input for this run* * * * * *
C* * * * *Block #1
      WRITE(6,340)RTIME
      WRITE(6,350)ATIME
      WRITE(6,360)ETIME
      IF(BMOVE.LE.0)THEN
             WRITE(6,370)
      ELSE
            WRITE(6,380)BMOVE
      ENDIF
      WRITE(6,390)HORIZ
      A=100.*PERCENT
      WRITE(6,400)A
212   WRITE(6,215)
215   FORMAT(' Would you like to change any of the above?   ')
      READ(6,'(A1)')RESP
      IF((RESP.EQ.'y').OR.(RESP.EQ.'Y')) THEN
             WRITE(6,220)
220   FORMAT(' Enter mission ready time (hours after start): (nn.nn) ')
             READ(5,'(F5.2)')RTIME
             WRITE(6,230)
230   FORMAT(/' Enter NBC attack time after start: (nn.nn)  ')
             READ(5,'(F5.2)')ATIME
             WRITE(6,240)
240   FORMAT(/' Enter TOE attrition time:  ')
             READ(5,'(F5.2)')ETIME
             WRITE(6,250)
250   FORMAT(' Enter aggregate unit movement time (-1. for none): (nn.nn
     *) ')
             READ(5,'(F5.2)')BMOVE
             WRITE(6,260)
260   FORMAT('/Enter the planning horizon for this run (hours):  (nn.nn)
     * ')
             READ(5,'(F5.2)')HORIZ
             WRITE(6,270)
270   FORMAT(/' Enter percent of BIP to be used as threshold:  ')
             READ(5,'(F4.2)')PERCENT
      ENDIF
      IF(RESP.NE.'Y'.AND.RESP.NE.'y'.AND.RESP.NE.'N'.AND.RESP.NE.'n')GOT
     *O 212
C* * * *Block #2
      WRITE(6,410)
      DO 275 I=1,NUNITS
             WRITE(6,420)I,SIP(I),ATT(I)
275   CONTINUE
276   WRITE(6,277)
277   FORMAT(' Would you like to change the BIPs?  ')
      READ(6,'(A1)')RESP
```

```
      IF((RESP.EQ.'y').OR.(RESP.EQ.'Y')) THEN
            WRITE(6,280)
280   FORMAT(' Enter BIP for each unit:')
            DO 290 I=1,NUNITS
                READ(5,'(F7.2)')SIP(I)
290         CONTINUE
      ENDIF
      IF(RESP.NE.'Y'.AND.RESP.NE.'y'.AND.RESP.NE.'N'.AND.RESP.NE.'n')GOT
     *O 276
C* * * * *Block #3
292   WRITE(6,295)
295   FORMAT(' Would you like to change the TOE attrition rates?   ')
      READ(6,'(A1)')RESP
      IF((RESP.EQ.'y').OR.(RESP.EQ.'Y')) THEN
            WRITE(6,297)
297   FORMAT(' Enter the TOE attrition rates for each unit: (n.nnnnn)'/)
            DO 298 I=1,NUNITS
                READ(5,'(F7.5)')ATT(I)
298         CONTINUE
      ENDIF
      IF(RESP.NE.'Y'.AND.RESP.NE.'y'.AND.RESP.NE.'N'.AND.RESP.NE.'n')GOT
     *O 292
C* * * * *Block #4
      WRITE(6,430)DEG
300   WRITE(6,310)
310   FORMAT(' Would you like to change the degradation rate?   ')
      READ(5,'(A1)')RESP
      IF((RESP.EQ.'y').OR.(RESP.EQ.'Y')) THEN
            WRITE(6,320)
320   FORMAT(' Enter degradation index: (n.nnnnn) ')
            READ(5,'(F7.5)')DEG
      ENDIF
      IF(RESP.NE.'Y'.AND.RESP.NE.'y'.AND.RESP.NE.'N'.AND.RESP.NE.'n')GOT
     *O 300
C* * * * * * Echo this data to the output file * * * * * *
      WRITE(7,340)RTIME
      WRITE(7,350)ATIME
      WRITE(7,360)ETIME
      IF(BMOVE.LE.0)THEN
            WRITE(7,370)
      ELSE
            WRITE(7,380)BMOVE
      ENDIF
      WRITE(7,390)HORIZ
      A=100.*PERCENT
      WRITE(7,400)A
      WRITE(7,410)
      DO 330 I=1,NUNITS
            WRITE(7,420)I,SIP(I),ATT(I)
330   CONTINUE
      WRITE(7,430)DEG
      A=100.*RESTMAX
```

```
      WRITE(7,440)A
340   FORMAT(/' Unit ready time is ',F5.2,' hours after start.')
350   FORMAT(/' NBC Attack time is ',F5.2,' hours after start.')
360   FORMAT(/' TOE attrition initiates at ',F5.2,' hours.'
     *)
370   FORMAT(/' Aggregate unit will be stationary through out the planni
     *ng window.')
380   FORMAT(/' Aggregate unit plans to move at ',F5.2,' hours.')
390   FORMAT(/' The planning horizon is ',F5.2,' hours.')
400   FORMAT(/' The unit power threshold (each unit) is ',F5.2,' percent
     * of its BIP'/)
410   FORMAT(' Unit#     BIP     Attrition Rate'/)
420   FORMAT(' ',1X,I3,6X,F7.2,8X,F6.4)
430   FORMAT(/' Degradation rate is: ',F7.5)
440   FORMAT(/' Maximum restoration from decon is : ',F6.2,' percent.')
C* * * * * * Check for threshold violation * * * * * *
      WRITE(7,460)
460   FORMAT(/18X,' <<<<<<<<<<Decision results follow>>>>>>>>>>'/)
      CALL POWER(VFLAG,NUNITS,VTIME,SIP,ABIP,B,CSIP,HORIZ,RTIME,ATIME,
     *DEG,ATT,ETIME,THRESH,MTIME,EPOWER,FPOWER,PERCENT)
C* * * * * * Test for decon requirements * * * * * *
      IF(MTIME.LT.HORIZ) THEN
            IF(BMOVE.LT.0) THEN
                WRITE(7,470)
470             FORMAT(/' En-route decon not possible.')
            ELSE
                CALL ENROUTE(NUNITS,BMOVE,SP,INDEX,ITEM,ATIME,ETIME,
     *DEG,EPOWER,FPOWER,UDTIME,DMAT,DSUM,MAXSITES,ATT,NSITES,ST,REST,
     *FSIP,DECR,ITER)
                GOTO 190
            ENDIF
C* * * * * * Dynamic Program call follows * * * * * *
            CALL DP(NSITES,NUNITS,LLIST,DPHEAD,DPTOTAL,STAGE,VAR,
     *DTM,WATER,TNODE,HNODE,MAXUNITS,ATIME,ORDER,DMAT,UTIME,STMAX,JJ,
     *DSUM,MAXSITES,ATT,DEG,EPOWER,FPOWER,UDTIME,ETIME,REST,FSIP,SAT,
     *DECR,ITER,HDTIME,VTIME,MTIME)
      ELSE
            WRITE(7,490)
      ENDIF
      GOTO 190
490   FORMAT(/' No threshold violation within planning window.'/' Decont
     *amination planning not required at this point.')
      END
C* * * * * END of main program * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<  Subroutine INPUT  >>>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      SUBROUTINE INPUT(EP,HEAD,DIST,NVERT,SITE,UNIT,DTM,NUNITS,NSITES
     *,WATER,SP,SPEED,ABIP,ETIME,HDTIME,TRUCK,HTRUCK,TRACK,ALPHA,SAT,
     *DEG,PERCENT,RTIME,ATIME,BMOVE,HORIZ,SIP,ATT)
C* * * * * Declare Variables * * * * *
      INTEGER EP(*),HEAD(*),SITE(*),UNIT(*),TRUCK(*),HTRUCK(*),TRACK(*)
```

```
      INTEGER V1,V2,EPP(51),START,FINISH,NVERT,DTM,NUNITS,NSITES
      INTEGER WATER,SP
      REAL ABIP(*),DIST(*),ALPHA(*),SAT(*),SIP(*),ATT(*)
      LOGICAL GRAPH
      PARAMETER (GRAPH=.FALSE.)
C* * * * * Open Data Files * * * * *
      OPEN(1,FILE='MAP.DAT')
      OPEN(2,FILE='SITES.DAT')
      OPEN(3,FILE='UNITS.DAT')
      OPEN(4,FILE='GENERAL.DAT')
      READ(1,'(3I10)')NVERT,START,FINISH
      I=0
      NSITES=0
      NUNITS=0
C* * * * * Read site data * * * * *
10    I=I+1
      READ(2,'(I3,F6.3)',END=20)V1,V3
      SITE(I)=V1
      SAT(I)=V3
      NSITES=NSITES+1
      GOTO 10
20    READ(3,'(I3)')DTM
      I=0
C* * * * * Read unit data * * * * *
30    I=I+1
      READ(3,'(4I3)',END=40)V1,V2,I1,I2
      UNIT(I)=V1
      TRUCK(I)=V2
      HTRUCK(I)=I1
      TRACK(I)=I2
      NUNITS=NUNITS+1
      GOTO 30
40    CONTINUE
C* * * * * First pass; compute degree of each node in map network* * * *
      DO 50 I=1,NVERT
50    EP(I)=0
60    READ(1,'(2I10)',END=70)V1,V2
      EP(V1+1)=EP(V1+1)+1
      EP(V2+1)=EP(V2+1)+1
      GOTO 60
70    EP(1)=1
      DO 80 I=2,NVERT+1
80    EP(I)=EP(I-1)+EP(I)
      DO 90 I=1,NVERT
90    EPP(I)=EP(I)
C* * * * * Second pass; determine forward star representaion * * * * *
      REWIND 1
      READ(1,'(3I10)')V1,V2,I1
100   READ(1,'(2I10,F5.1,F5.3)',END=102)V1,V2,V3,V4
      HEAD(EPP(V1))=V2
      DIST(EPP(V1))=V3
      ALPHA(EPP(V1))=V4
```

```
      EPP(V1)=EPP(V1)+1
      HEAD(EPP(V2))=V1
      DIST(EPP(V2))=V3
      ALPHA(EPP(V2))=V4
      EPP(V2)=EPP(V2)+1
      GOTO 100
C* * * * * Other miscl. data * * * * *
102   READ(4,'(2I3)')WATER,SP
      READ(4,'(5F6.2)')RTIME,ATIME,ETIME,BMOVE,HORIZ
      READ(4,'(2F6.2,2F6.3)')SPEED,PERCENT,DEG,HDTIME
      I=1
103   READ(4,'(2F8.2,F6.3)',END=105)ABIP(I),SIP(I),ATT(I)
      I=I+1
      GOTO 103
C* * * * * Close data files, file input complete * * * * *
105   CLOSE(1,STATUS='KEEP')
      CLOSE(2,STATUS='KEEP')
      CLOSE(3,STATUS='KEEP')
      CLOSE(4,STATUS='KEEP')
C* * *Echo the input data * * * * *
      WRITE(7,109)
109   FORMAT(/' NOTE:  Time units are HOURS; distance units are KILOMETE
     *RS')
      IF(GRAPH) THEN
            WRITE(7,110)NVERT,START,FINISH
110         FORMAT(/I5,' Vertices read, with ',I5,' as the start, and
     *',I5,' as the finish vertices.')
            WRITE(7,120)
120         FORMAT(' VERTEX     ADJACENT TO:      DISTANCE      SPEED
     * INDEX'/)
            DO 132 I=1,NVERT
                DO 130 J=EP(I),EP(I+1)-1
                        WRITE(7,140)I,HEAD(J),DIST(J),ALPHA(J)
130             CONTINUE
132         CONTINUE
      ELSE
            WRITE(7,145)
      ENDIF
140   FORMAT(' ',3X,I3,12X,I3,8X,F5.1,12X,F5.3)
145   FORMAT(/' Network graph echo is turned off')
      WRITE(7,150)
150   FORMAT(/' Location of Decon Sites:'/)
      WRITE(7,160)
160    FORMAT('    Site#     Node      Time Index'/)
      DO 170 I=1,NSITES
      WRITE(7,180)I,SITE(I),SAT(I)
170   CONTINUE
180   FORMAT(' ',4X,I3,7X,I3,12X,F5.3)
      WRITE(7,190)DTM
190   FORMAT(/' Location of decon team is decon site: ',I3/)
      WRITE(7,200)
200   FORMAT(' Location of Units:'/)
```

```
      WRITE(7,210)
210   FORMAT('      Unit#    Node    Trks    Hvy Trks     Tracks'/)
      DO 220 I=1,NUNITS
      WRITE(7,230)I,UNIT(I),TRUCK(I),HTRUCK(I),TRACK(I)
220   CONTINUE
230   FORMAT(' ',4X,I3,6X,I3,6X,I3,7X,I3,9X,I3)
      WRITE(7,250)SP
250   FORMAT(/' Aggregate unit anticipated point of departure at/near si
     *te: ',I3)
      WRITE(7,270)SPEED,HDTIME
270   FORMAT(/' Maximum speed of slowest vehicle: ',F5.2/' Decon time pe
     *r vehicle (base case): ',F7.4/)
      WRITE(7,280)
280   FORMAT('   Unit #          Initial ABIP'/)
      DO 290 I=1,NUNITS
      WRITE(7,300)I,ABIP(I)
290   CONTINUE
300   FORMAT(' ',4X,I3,16X,F6.2)
      RETURN
      END
C* * * * * End of INPUT * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<  Subroutine POWER  >>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      SUBROUTINE POWER(VFLAG,NUNITS,VTIME,SIP,ABIP,B,CSIP,HORIZ,RTIME,
     *ATIME,DEG,ATT,ETIME,THRESH,MTIME,EPOWER,FPOWER,PERCENT)
      INTEGER VFLAG(*),CHSTATE
      REAL VTIME(*),SIP(*),ABIP(*),B(*),CSIP(*)
      REAL ATT(*),ETIME,THRESH(*),MTIME,EPOWER(*),FPOWER(*)
C* * * * * * Initialize variables * * * * * *
      DO 10 I=1,NUNITS
            B(I)=(ALOG(SIP(I)/ABIP(I)))/RTIME
            VFLAG(I)=0
            VTIME(I)=1.E7
10    CONTINUE
      DO 12 I=1,NUNITS
            WRITE(7,15)I,B(I)
12    CONTINUE
15    FORMAT(' Unit ',I2,' preparation coeff = ',F7.4)
C* * * * * * Determine which case applies to this attack * * * * * *
      IF(ATIME.LT.RTIME) THEN
C* * * * * * Case I; attack before ready time * * * * * *
            DO 20 I=1,NUNITS
                 THRESH(I)=SIP(I)*PERCENT
                 CHSTATE=-1
                 CSIP(I)=PREP(ABIP(I),ATIME,B(I),DEG,CHSTATE)
                 TIME=RTIME-ATIME
                 CHSTATE=1
                 CSIP(I)=PREP(CSIP(I),TIME,B(I),DEG,CHSTATE)
                 FPOWER(I)=CSIP(I)
C* * * Check #1, between ready time and engagement time
                 TIME=ETIME-RTIME
```

```
                OLD=CSIP(I)
                CSIP(I)=DEGRADE(CSIP(I),TIME,DEG)
                EPOWER(I)=CSIP(I)
                IF(CSIP(I).LT.THRESH(I))THEN
                        DT=(ALOG(THRESH(I)/OLD))/(-DEG)
                        VTIME(I)=RTIME+DT
                        VFLAG(I)=1
                ENDIF
C* * *Check #2, between engagement time and planning window
              TIME=HORIZ-ETIME
              OLD=CSIP(I)
              CSIP(I)=ATTRIT(CSIP(I),TIME,ATT(I),DEG)
                IF((CSIP(I).LT.THRESH(I)).AND.(VFLAG(I).EQ.0))THEN
                        DT=(ALOG(THRESH(I)/OLD)/(-(ATT(I)+DEG)))
                        VTIME(I)=ETIME+DT
                        VFLAG(I)=1
                ENDIF
20          CONTINUE
      ELSE IF(ATIME.GE.RTIME)THEN
C* * * * * * Case II; attack after ready time * * * * * *
            DO 30 I=1,NUNITS
                THRESH(I)=SIP(I)*PERCENT
                CSIP(I)=SIP(I)
                FPOWER(I)=SIP(I)
30          CONTINUE
            DO 40 I=1,NUNITS
C* * * Check #1 between attack time and engagement time
                CHSTATE=1
                TIME=ETIME-ATIME
                OLD=CSIP(I)
                CSIP(I)=DEGRADE(CSIP(I),TIME,DEG)
                EPOWER(I)=CSIP(I)
                IF(CSIP(I).LT.THRESH(I))THEN
                        DT=(ALOG(THRESH(I)/OLD))/(-DEG)
                        VTIME(I)=ATIME+DT
                        VFLAG(I)=1
                ENDIF
C* * * Check #2 between engagement time and planning window
                TIME=HORIZ-ETIME
                OLD=CSIP(I)
                CSIP(I)=ATTRIT(CSIP(I),TIME,ATT(I),DEG)
                IF((CSIP(I).LT.THRESH(I)).AND.(VFLAG(I).EQ.0))THEN
                        DT=(ALOG(THRESH(I)/OLD)/(-(ATT(I)+DEG)))
                        VTIME(I)=ETIME+DT
                        VFLAG(I)=1
                ENDIF
40          CONTINUE
      END IF
C* * * * * Report Results * * * * *
      WRITE(7,50)
50    FORMAT(/' Power of each unit at end of the planning window:')
      DO 60 I=1,NUNITS
```

```
            WRITE(7,70)I,CSIP(I)
60    CONTINUE
70    FORMAT(' Unit',I2,' will be at ',F7.2,' STAPOWs.')
      MTIME=1.E7
      DO 80 I=1,NUNITS
            IF(MTIME.GT.VTIME(I)) THEN
                MTIME=VTIME(I)
            ENDIF
80    CONTINUE
      DO 90 I=1,NUNITS
            IF(VTIME(I).LT.HORIZ) WRITE(7,100)I,THRESH(I),VTIME(I)
90    CONTINUE
100   FORMAT(/' Unit ',I2,' will violate threshold (',F7.2,') at hour ',
     *F6.2,'.')
      RETURN
      END
C* * * * * End of POWER
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<  Subroutine ENROUTE  >>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      SUBROUTINE ENROUTE(NUNITS,BMOVE,SP,INDEX,ITEM,ATIME,ETIME,
     *DEG,EPOWER,FPOWER,UDTIME,DMAT,I1,I2,ATT,NSITES,ST,REST,FSIP,
     *DECR,ITER)
C* * * * * Declare Variables * * * * *
      INTEGER SP,INDEX(*),NUNITS
      REAL BMOVE,START,AVAIL,ITEM(*),ST(*),DMAT(I1,I2),ATT(*)
      REAL UDTIME(*),EPOWER(*),FPOWER(*),FSIP(*),REST(*)
C* * * * *Hasty Decon results* * * * *
      PERCENT=1.
      WRITE(7,10)SP
10    FORMAT(/' Enroute Decon Option Chosen'/' Decon operations will be
     *at site ',I3,'.')
      WRITE(7,15)
15    FORMAT(/' Results for partial decon times follow ...')
      DO 20 I=1,NUNITS
            ITEM(I)=DMAT((NSITES+I),SP)
20    CONTINUE
      CALL BSORT(ITEM,NUNITS,INDEX)
C* * * * * This loop will solve problem with
C* * * * * varying degrees of decon time.
      DO 120 K=1,ITER
            WRITE(7,110)PERCENT
            J=INDEX(1)
            AVAIL=ITEM(1)+UDTIME(J)*PERCENT
            ST(J)=ITEM(1)
            DO 30 I=2,NUNITS
                J=INDEX(I)
                IF(ITEM(I).LT.AVAIL) THEN
                          ST(J)=AVAIL
                          AVAIL=AVAIL+UDTIME(J)*PERCENT
                ELSE
                          AVAIL=AVAIL+(ITEM(I)-AVAIL)+UDTIME(J)*PERCE
```

```
     *NT
                              ST(J)=AVAIL-(UDTIME(J)*PERCENT)
                         ENDIF
30               CONTINUE
                 A=BMOVE-AVAIL
                 IF (A.LT.ATIME) THEN
                      BB=(ATIME+AVAIL)-BMOVE
                      START=ATIME
                      WRITE(7,40)AVAIL,START
                      DO 35 I=1,NUNITS
                              WRITE(7,60)INDEX(I)
35                    CONTINUE
                      WRITE(7,70)BB
                 ELSE
                      START=A
                      WRITE(7,40)AVAIL,START
40    FORMAT(/' Decon operation will require ',F6.2,' hours.'
     */' Units must move out NLT hour ',F6.2//' Units will arrive in the
     * following order:'/)
                      DO 50 I=1,NUNITS
                              WRITE(7,60)INDEX(I)
50                    CONTINUE
                      ENDIF

60    FORMAT('     Unit ',I3)
70    FORMAT(/' Immediate execution of decon operation will still '/
     *'delay departure by ',F6.2,' hours.')
                 DO 80 I=1,NUNITS
                      TIME=ST(I)+START
                      IF(TIME.LT.ETIME) THEN
                              ZTIME=TIME-ATIME
                              CSIP=DEGRADE(FPOWER(I),ZTIME,DEG)
                      ELSE
                              ZTIME=TIME-ETIME
                              CSIP=ATTRIT(EPOWER(I),ZTIME,ATT(I),DEG)
                      ENDIF
                      REST(I)=RCOEFF(FPOWER(I),CSIP,UDTIME(I))
                      FSIP(I)=RESTORE(CSIP,UDTIME(I),REST(I),PERCENT)
80               CONTINUE
                 DO 90 I=1,NUNITS
                      WRITE(7,100)I,FSIP(I),REST(I)
90               CONTINUE
100   FORMAT(' Unit ',I2,' Final Power = ',F8.2,'; Restore Coeff = ',F7.
     *4)
110   FORMAT(/' ******** Fraction of full decon time realized: ',F5.3,'*
     *********')
                 PERCENT=PERCENT-DECR
120   CONTINUE
      RETURN
      END
C* * * * * End of ENROUTE * * * * *
C*************************************************************************
```

```
C*<<<<<<<<<<<<<<<<<<<<<<<<  Subroutine DP  >>>>>>>>>>>>>>>>>>>>>>>>>>>>**
C**********************************************************************
      SUBROUTINE DP(NSITES,NUNITS,LLIST,DPHEAD,DPTOTAL,STAGE,VAR,
     *DTM,WATER,TNODE,HNODE,MAXUNITS,ATIME,ORDER,DMAT,UTIME,I1,J1,I2,
     *J2,ATT,DEG,EPOWER,FPOWER,UDTIME,ETIME,REST,FSIP,SAT,DECR,ITER,
     *HDTIME,VTIME,MTIME)
C* * * * * Define variables * * * * *
      REAL DMAT(I2,J2),DPTOTAL(*),UTIME(I1,J1),MTIME,FSIP(*),VTIME(*)
      REAL FPOWER(*),EPOWER(*),UDTIME(*),ATT(*),REST(*),SAT(*)
      INTEGER NSITES,NUNITS,BINO
      INTEGER DPHEAD(*),STAGE(0:*),VAR(*),POINT,COUNT,FROM,TO,DPUNIT
      INTEGER DPSITE,STCOUNT,FINDEX,TINDEX,T,H,DTM,LLIST(*)
      INTEGER TNODE(*),HNODE(*),WATER,ORDER(*),DPDTM
C* * * * *Comput number of states in DP graph* * * * *
      NUMSTS=0
      DO 30 I=0,NUNITS
            NUMSTS=NUMSTS+(BINO(NUNITS,I)*NSITES)
30    CONTINUE
C* * * * *Build Linked List for state attributes in DP graph* * * * *
C* * *Build stage 0
      STCOUNT=0
      STAGE(0)=1
      POINT=1
      INDEX=(NUMSTS)*(NUNITS+2)
      DO 60 I=1,INDEX
            LLIST(I)=0
60    CONTINUE
      DO 70 I=1,NSITES
            STCOUNT=STCOUNT+1
            LLIST(POINT)=STCOUNT
            LLIST(POINT+1)=I
            POINT=POINT+NUNITS+2
70    CONTINUE
C* * *Initialize variables to initial combination, stage loops here.
      DO 160 I=1,NUNITS
            STAGE(I)=POINT
            COUNT=1
            DO 90 J=1,I
                 VAR(J)=COUNT
                 COUNT=COUNT+1
90          CONTINUE
            DO 100 J=(I+1),MAXUNITS
                 VAR(J)=0
100         CONTINUE
C* * *Each combo loops here.
110         DO 135 J=1,NSITES
                 STCOUNT=STCOUNT+1
                 LLIST(POINT)=STCOUNT
                 LLIST(POINT+1)=J
                 DO 130 L=1,I
                          LLIST(POINT+1+VAR(L))=1
130              CONTINUE
```

```
                POINT=POINT+NUNITS+2
135          CONTINUE
             VAR(I)=VAR(I)+1
             IF(VAR(I).LE.NUNITS)GOTO 110
C* * *Increment combo variables since outer variable has reached limit.
             COUNT=0
             DO 140 J=(I-1),1,-1
                  IF(VAR(J).EQ.(NUNITS-(I-J)))COUNT=COUNT+1
140          CONTINUE
             IF(COUNT.EQ.(I-1)) GOTO 160
             VAR(I-COUNT-1)=VAR(I-COUNT-1)+1
             DO 150 J=(I-COUNT),I
                  VAR(J)=VAR(J-1)+1
150          CONTINUE
             GOTO 110
160   CONTINUE
C* * * * *Start DP computations* * * * *
      DO 170 I=1,NSITES
             DPTOTAL(I)=0.
170   CONTINUE
      DO 180 I=(NSITES+1),NUMSTS
             DPTOTAL(I)=1.E7
180   CONTINUE
      DO 190 I=1,NUNITS
             TO=STAGE(I-1)
             FROM=STAGE(I)
             TINDEX=NSITES*BINO(NUNITS,(I-1))
             FINDEX=NSITES*BINO(NUNITS,I)
             DO 200 J=1,FINDEX
                  DO 210 K=1,TINDEX
                           DO 220 L=1,NUNITS
                                    IF(((LLIST(FROM+1+L)).EQ.0).AND.
    *((LLIST(TO+1+L)).EQ.1)) GOTO 205
220                         CONTINUE
                            DPDTM=LLIST(FROM+1)
                            DPSITE=LLIST(TO+1)
                            DO 230 L=1,NUNITS
                                    IF(((LLIST(FROM+1+L)).EQ.1).AND.
    *((LLIST(TO+1+L)).EQ.0)) DPUNIT=L
230                       CONTINUE
                          UNITDIST=DMAT((NSITES+DPUNIT),DPSITE)
                          DTMDIST=DMAT(DPDTM,DPSITE)
                       IF(MOD(((NUNITS+1)-I),WATER).EQ.0)THEN
                          DPDIST=MAX(UNITDIST,DTMDIST)+(3.*HDTIME)
                       ELSE
                          DPDIST=MAX(UNITDIST,DTMDIST)
                       ENDIF
                          JJJ=LLIST(FROM)-NSITES
                          DPARC=DPDIST+UNITDIST
                          U1=DPDIST
                          U3=UNITDIST
                          DPARC=DPARC+(UDTIME(DPUNIT)*SAT(DPSITE))
```

```
                    U2=UDTIME(DPUNIT)*SAT(DPSITE)
                    CHECK=DPARC+DPTOTAL(LLIST(TO))
                  IF(CHECK.LT.DPTOTAL(LLIST(FROM)))THEN
                      DPTOTAL(LLIST(FROM))=CHECK
                      DPHEAD(JJJ)=LLIST(TO)
                      ORDER(JJJ)=DPUNIT
                      UTIME(JJJ,1)=U1
                      UTIME(JJJ,2)=U2
                      UTIME(JJJ,3)=U3
                  ENDIF
205                   TO=TO+NUNITS+2
210             CONTINUE
                FROM=FROM+NUNITS+2
                TO=STAGE(I-1)
200         CONTINUE
190   CONTINUE
      DPHEAD(NUMSTS-NSITES+1)=0
      H=NUMSTS-(NSITES-DTM)
      DO 240 I=1,NUNITS
            T=H
            TNODE(I)=T
            H=DPHEAD(T-NSITES)
            HNODE(I)=H
240   CONTINUE
C* * * * *Compute latest start time for decon operations* * * * *
      WRITE(7,242)
242   FORMAT(/' In place decon operation is chosen.')
      PERCENT=1.
      DO 310 L=1,ITER
            TIME=0.
            DO 245 I=1,NUNITS
                J=TNODE(I)-NSITES
                I1=ORDER(J)
                T2=TIME
                T3=UTIME(J,1)
                T4=UTIME(J,2)*PERCENT
                T5=UTIME(J,3)
                T6=T2+T3+T4+T5
                TIME=T6
                IF((VTIME(I1)-MTIME).LT.(T2+T3))THEN
                        START=VTIME(I1)-(T2+T3)
                        IF(START.LT.ATIME) START=ATIME
                ENDIF
245         CONTINUE
            WRITE(7,247)PERCENT
247   FORMAT(/' *********Fraction of full decon realized is: ',F5.3,'***
     *******')
            WRITE(7,250)
250   FORMAT(/' Decontamination Scheme:'/18X,' Init',4X,' Decon',3X,' Fi
     *nal'/' Unit',4X,' Start',3X,' Move',4X,' Time',4X,' Move',5X,' Fin
     *ish',3X,' Site')
            TIME=START
```

```
            DO 260 I=1,NUNITS
                 J=TNODE(I)-NSITES
                 I1=ORDER(J)
                 T2=TIME
                 T3=UTIME(J,1)
                 T4=UTIME(J,2)*PERCENT
                 T5=UTIME(J,3)
                 T6=T2+T3+T4+T5
                 STIME=T2+T3
                 IF(STIME.LT.ETIME) THEN
                          ZTIME=STIME-ATIME
                          CSIP=DEGRADE(FPOWER(I1),ZTIME,DEG)
                 ELSE
                          ZTIME=STIME-ETIME
                          CSIP=ATTRIT(EPOWER(I1),ZTIME,ATT(I1),DEG)
                 ENDIF
                 REST(I1)=RCOEFF(FPOWER(I1),CSIP,UDTIME(I1))
                 FSIP(I1)=RESTORE(CSIP,UDTIME(I1),REST(I1),PERCENT)
                 I7=LLIST((HNODE(I)-1)*(NUNITS+2)+2)
                 TIME=T6
                 WRITE(7,270)I1,T2,T3,T4,T5,T6,I7
260          CONTINUE
270   FORMAT(2X,I2,4X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2,5X,F6.2,5X,I2)
      A=TIME-START
      WRITE(7,280)A
280   FORMAT(/' Total time used (in hours) for decon operations is ',
     *F6.2)
            DO 290 I=1,NUNITS
                 WRITE(7,300)I,FSIP(I),REST(I)
290          CONTINUE
300   FORMAT(' Unit ',I2,' Final Power = ',F9.4,'; Restore Coeff = ',F7.
     *4)
            PERCENT=PERCENT-DECR
310   CONTINUE
      RETURN
      END
C* * * * * End of DP * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<<  Subroutine PATH  >>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      SUBROUTINE PATH(COST,D,EP,HEAD,PRED,V,IS)
      INTEGER EP(*),HEAD(*),PRED(*),VMIN,V
      REAL COST(*),D(*)
C* * * Set d(v) values to infinity.
C* * * Set predecessor for each vertex equal to zero.
C* * * Initialize pred(IS) and d(IS).
      DO 10 I=1,V
            D(I)=1.0E7
 10   CONTINUE
      D(IS)=0.
      DO 20 I=1,V
            PRED(I)=0
```

```
 20   CONTINUE
      PRED(IS)=IS
C* * * Main loop.
      DO 50 I=1,V
              DMIN=1E7
C* * * Find vertex with min d(v) not in S.
              DO 30 J=1,V
                   IF((PRED(J).LT.0).OR.(D(J).GT.DMIN)) GOTO 30
                   VMIN=J
                   DMIN=D(J)
 30           CONTINUE
C* * * Mark as a member of S.
              PRED(VMIN)=PRED(VMIN)*(-1)
C* * * Update incident d(v) and pred(v) values.
              DO 40 J=EP(VMIN),(EP(VMIN+1)-1)
                   IF((D(VMIN)+COST(J)).GT.D(HEAD(J))) GOTO 40
                   D(HEAD(J))=D(VMIN)+COST(J)
                   PRED(HEAD(J))=VMIN
 40           CONTINUE
 50   CONTINUE
      RETURN
      END
C* * * * * End of PATH * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<  Subroutine BSORT  >>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      SUBROUTINE BSORT(ITEM,N,INDEX)
      INTEGER INDEX(*),PAIRS
      REAL ITEM(*)
      LOGICAL DONE
      PAIRS=N-1
      DONE=.FALSE.
      DO 10 I=1,N
              INDEX(I)=I
10    CONTINUE
20    IF(.NOT. DONE) THEN
              DONE=.TRUE.
              DO 30 I=1,PAIRS
                   IF(ITEM(I).GT.ITEM(I+1)) THEN
                            TEMP=ITEM(I)
                            ITEM(I)=ITEM(I+1)
                            ITEM(I+1)=TEMP
                            ITEMP=INDEX(I)
                            INDEX(I)=INDEX(I+1)
                            INDEX(I+1)=ITEMP
                            DONE=.FALSE.
                   ENDIF
30            CONTINUE
              PAIRS=PAIRS-1
              GOTO 20
      ENDIF
      RETURN
```

```
      END
C* * * * * End BSORT * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<<<  Function BINO  >>>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION BINO(N,K)
      INTEGER BINO
      REAL NFAC,KFAC,NKFAC
      TOTAL=1.
      IF((K.EQ.0).OR.(K.EQ.N))THEN
             BINO=1
             RETURN
      ELSE
             DO 10 I=1,N
                  A=I
                  TOTAL=TOTAL*A
                  IF(I.EQ.(N-K))NKFAC=TOTAL
                  IF(I.EQ.K)KFAC=TOTAL
10           CONTINUE
             NFAC=TOTAL
             A=NFAC/(KFAC*NKFAC)
      ENDIF
      BINO=A
      RETURN
      END
C* * * * * End of BINO * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<  Function PREP  >>>>>>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION PREP(ABIP,TIME,B,DEG,CHSTATE)
      INTEGER CHSTATE
      IF(CHSTATE.EQ.1) THEN
             PREP=ABIP*EXP((B-DEG)*TIME)
      ELSE
             PREP=ABIP*EXP(B*TIME)
      ENDIF
      RETURN
      END
C* * * * * End of PREP * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<<<< Function DEGRADE >>>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION DEGRADE(CSIP,TIME,DEG)
      DEGRADE=CSIP*EXP((-1.)*DEG*TIME)
      RETURN
      END
C* * * * * End of DEGRADE * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<<  Function ATTRIT  >>>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION ATTRIT(CSIP,TIME,ATT,DEG)
      ATTRIT=CSIP*EXP((-1.)*(ATT+DEG)*TIME)
```

```
      RETURN
      END
C* * * * * End of ATTRIT * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<  Function RCOEFF  >>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION RCOEFF(SIP,CSIP,DTIME)
      PARAMETER (PERCENT=.8)
      RSIP=((SIP-CSIP)*PERCENT)+CSIP
      RCOEFF=(ALOG(RSIP/CSIP))/DTIME
      RETURN
      END
C* * * * * End of RCOEFF * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<  Function RESTORE  >>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
      FUNCTION RESTORE(CSIP,DTIME,REST,PERCENT)
      RESTORE=CSIP*EXP(REST*PERCENT*DTIME)
      RETURN
      END
C* * * * * End of RESTORE * * * * *
C*************************************************************************
C*<<<<<<<<<<<<<<<<<<<<<<<<  END OF SOURCE CODE  >>>>>>>>>>>>>>>>>>>>>>>>**
C*************************************************************************
```

APPENDIX B
OUTPUT FOR BASECASE SCENARIO

This appendix contains the actual model output for the base case scenario.

```
 Land Combat decision program for
 NBC Decontamination Operations.

 CPT John C. Roberts
 U.S. Navy Postgraduate School


<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

 NOTE:  Time units are HOURS; distance units are KILOMETERS

 Network graph echo is turned off

 Location of Decon Sites:

    Site#      Node       Time Index

       1         32            1.000
       2         27            1.000
       3         26            1.000
       4         19            1.000
       5          9            1.000
       6          2            1.000
       7         20            1.000
       8         22            1.000
       9         21            1.000
      10         14            1.000

 Location of decon team is decon site:  10

 Location of Units:

      Unit#     Node     Trks     Hvy Trks      Tracks

       1         8        20         10           10
       2         1         5          5           30
       3        18        20         20            0
       4        31        10         10           20
```

Aggregate unit anticipated point of departure at/near site: 8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP
1	500.00
2	400.00
3	300.00
4	350.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
2	.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37
3	.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
4	.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

```
 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4      13.46     0.20      2.60      0.20       16.46       7
   3      16.46     0.46      2.20      0.46       19.58       6
   1      19.58     0.25      2.35      0.10       22.28       6
   2      22.28     0.04      2.80      0.04       25.17       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1109.2460; Restore Coeff =  0.1687
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
```

```
Unit  3 Final Power =  913.5319; Restore Coeff =  0.2163
Unit  4 Final Power =  833.6650; Restore Coeff =  0.1474
```

APPENDIX C
OUTPUT FOR SENSITIVITY ANALYSIS

This appendix contains output from several runs pertaining to the sensitivity analysis done in chapter 4.

UNIT TWO SENSITIVITY ANALYSIS

```
Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School


<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE:  Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:
```

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

```
Location of decon team is decon site:  10

Location of Units:
```

Unit#	Node	Trks	Hvy Trks	Tracks
1	8	20	10	10
2	1	5	5	30

3	18	20	20	0
4	31	10	10	20

Aggregate unit anticipated point of departure at/near site: 8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP
1	500.00
2	400.00
3	300.00
4	350.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	0.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
2	0.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37
3	0.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
4	0.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

```
 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.2000
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at    0.15 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  10.61.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4        2.00    0.20      2.60      0.20        5.01       7
   3        5.01    0.46      2.20      0.46        8.13       6
   1        8.13    0.25      2.35      0.10       10.83       6
   2       10.83    0.04      2.80      0.04       13.71       6

 Total time used (in hours) for decon operations is  11.71
```

```
 Unit  1 Final Power = 1170.4730; Restore Coeff =  0.0453
 Unit  2 Final Power =  983.7753; Restore Coeff =  0.2285
 Unit  3 Final Power =  986.6056; Restore Coeff =  0.0254
 Unit  4 Final Power =  899.2707; Restore Coeff =  0.0012

 ******** Run number   2 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.1797
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at    0.33 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  10.87.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.
```

```
 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                      Init      Decon     Final
 Unit      Start      Move      Time      Move       Finish    Site
   4        2.00      0.20      2.60      0.20        5.01       7
   3        5.01      0.46      2.20      0.46        8.13       6
   1        8.13      0.25      2.35      0.10       10.83       6
   2       10.83      0.04      2.80      0.04       13.71       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1170.4730; Restore Coeff =  0.0453
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  986.6055; Restore Coeff =  0.0254
 Unit  4 Final Power =  899.2705; Restore Coeff =  0.0012

 ******** Run number   3 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.1600
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>
```

```
Unit  1 preparation coeff =  0.8755
Unit  2 preparation coeff =  1.0116
Unit  3 preparation coeff =  1.2040
Unit  4 preparation coeff =  0.9445

Power of each unit at end of the planning window:
Unit 1 will be at  320.56 STAPOWs.
Unit 2 will be at    0.73 STAPOWs.
Unit 3 will be at  120.03 STAPOWs.
Unit 4 will be at   72.41 STAPOWs.

Unit  1 will violate threshold ( 600.00) at hour  27.10.

Unit  2 will violate threshold ( 550.00) at hour  11.18.

Unit  3 will violate threshold ( 500.00) at hour  19.46.

Unit  4 will violate threshold ( 450.00) at hour  17.55.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                  Init      Decon     Final
Unit      Start   Move      Time      Move       Finish    Site
  4        2.31   0.20      2.60      0.20        5.32       7
  3        5.32   0.46      2.20      0.46        8.44       6
  1        8.44   0.25      2.35      0.10       11.14       6
  2       11.14   0.04      2.80      0.04       14.03       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1168.4990; Restore Coeff =  0.0486
Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
Unit  3 Final Power =  985.4368; Restore Coeff =  0.0277
Unit  4 Final Power =  898.1478; Restore Coeff =  0.0032

******** Run number   4 **********


Unit ready time is  1.00 hours after start.

NBC Attack time is  2.00 hours after start.

TOE attrition initiates at  8.00 hours.

Aggregate unit will be stationary through out the planning
window.

The planning horizon is 48.00 hours.
```

```
 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.05000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at   80.65 STAPOWs.
 Unit 2 will be at   49.55 STAPOWs.
 Unit 3 will be at   30.20 STAPOWs.
 Unit 4 will be at   18.22 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  14.55.

 Unit  2 will violate threshold ( 550.00) at hour  13.62.

 Unit  3 will violate threshold ( 500.00) at hour  12.91.

 Unit  4 will violate threshold ( 450.00) at hour  12.37.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4        4.75    0.20      2.60      0.20        7.75       7
   3        7.75    0.46      2.20      0.46       10.87       6
   1       10.87    0.25      2.35      0.10       13.57       6
   2       13.57    0.04      2.80      0.04       16.46       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1107.4220; Restore Coeff =  0.1732
```

```
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  945.6675; Restore Coeff =  0.1187
 Unit  4 Final Power =  875.3200; Restore Coeff =  0.0460

 ******** Run number   5 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.07167

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at   29.76 STAPOWs.
 Unit 2 will be at   18.29 STAPOWs.
 Unit 3 will be at   11.14 STAPOWs.
 Unit 4 will be at    6.72 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  11.22.

 Unit  2 will violate threshold ( 550.00) at hour  10.87.

 Unit  3 will violate threshold ( 500.00) at hour  10.59.

 Unit  4 will violate threshold ( 450.00) at hour  10.36.
```

```
 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                      Init      Decon     Final
 Unit      Start      Move      Time      Move       Finish    Site
   4        2.00      0.20      2.60      0.20        5.01       7
   3        5.01      0.46      2.20      0.46        8.13       6
   1        8.13      0.25      2.35      0.10       10.83       6
   2       10.83      0.04      2.80      0.04       13.71       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1111.3930; Restore Coeff =  0.1634
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  956.0041; Restore Coeff =  0.0925
 Unit  4 Final Power =  897.3954; Restore Coeff =  0.0045

 ******** Run number   6 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 0.09000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
```

```
Unit  2 preparation coeff =  1.0116
Unit  3 preparation coeff =  1.2040
Unit  4 preparation coeff =  0.9445

Power of each unit at end of the planning window:
Unit 1 will be at   12.81 STAPOWs.
Unit 2 will be at    7.87 STAPOWs.
Unit 3 will be at    4.80 STAPOWs.
Unit 4 will be at    2.89 STAPOWs.

Unit  1 will violate threshold ( 600.00) at hour   9.53.

Unit  2 will violate threshold ( 550.00) at hour   9.39.

Unit  3 will violate threshold ( 500.00) at hour   9.28.

Unit  4 will violate threshold ( 450.00) at hour   9.18.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                  Init      Decon     Final
Unit      Start   Move      Time      Move       Finish    Site
  4        2.00   0.20      2.60      0.20        5.01       7
  3        5.01   0.46      2.20      0.46        8.13       6
  1        8.13   0.25      2.35      0.10       10.83       6
  2       10.83   0.04      2.80      0.04       13.71       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1094.6980; Restore Coeff =  0.2067
Unit  2 Final Power =  973.4968; Restore Coeff =  0.2620
Unit  3 Final Power =  946.4051; Restore Coeff =  0.1168
Unit  4 Final Power =  896.7413; Restore Coeff =  0.0056
```

OTHER UNIT BREAK POINTS

Land Combat decision program for
NBC Decontamination Operations.

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U.S. Navy Postgraduate School

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 10

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	8	20	10	10
2	1	5	5	30
3	18	20	20	0
4	31	10	10	20

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP

1	500.00
2	400.00
3	300.00
4	350.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
2	.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37
3	.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
4	.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	1.4883
2	1100.00	0.0200
3	1000.00	0.0300
4	900.00	0.0400

```
 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at    0.00 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour   8.38.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4        2.00    0.20      2.60      0.20        5.01       7
   3        5.01    0.46      2.20      0.46        8.13       6
   1        8.13    0.25      2.35      0.10       10.83       6
   2       10.83    0.04      2.80      0.04       13.72       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1080.0000; Restore Coeff =  0.2501
 Unit  2 Final Power = 1053.9330; Restore Coeff =  0.0686
 Unit  3 Final Power =  986.5907; Restore Coeff =  0.0254
 Unit  4 Final Power =  899.2563; Restore Coeff =  0.0013

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish
Site
```

```
   4       3.20      0.20      1.95      0.20       5.56       7
   3       5.56      0.46      1.65      0.46       8.13       6
   1       8.13      0.25      1.76      0.10      10.24       6
   2      10.24      0.04      2.10      0.04      12.43       6

 Total time used (in hours) for decon operations is   9.23
 Unit  1 Final Power =  932.4073; Restore Coeff =  0.2501
 Unit  2 Final Power = 1013.3850; Restore Coeff =  0.0616
 Unit  3 Final Power =  968.7213; Restore Coeff =  0.0295
 Unit  4 Final Power =  889.9685; Restore Coeff =  0.0087

 *********Fraction of full decon realized is: 0.500*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish
Site
   4       4.40      0.20      1.30      0.20       6.11       7
   3       6.11      0.46      1.10      0.46       8.13       6
   1       8.13      0.25      1.18      0.10       9.65       6
   2       9.65      0.04      1.40      0.04      11.14       6

 Total time used (in hours) for decon operations is   6.74
 Unit  1 Final Power =  804.9846; Restore Coeff =  0.2501
 Unit  2 Final Power =  984.0236; Restore Coeff =  0.0547
 Unit  3 Final Power =  946.9473; Restore Coeff =  0.0335
 Unit  4 Final Power =  872.3741; Restore Coeff =  0.0161

 *********Fraction of full decon realized is: 0.250*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4       5.60      0.20      0.65      0.20       6.66       7
   3       6.66      0.46      0.55      0.46       8.13       6
   1       8.13      0.25      0.59      0.10       9.07       6
   2       9.07      0.04      0.70      0.04       9.86       6

 Total time used (in hours) for decon operations is   4.25
 Unit  1 Final Power =  694.9754; Restore Coeff =  0.2501
 Unit  2 Final Power =  964.8965; Restore Coeff =  0.0477
 Unit  3 Final Power =  921.5350; Restore Coeff =  0.0376
 Unit  4 Final Power =  846.9122; Restore Coeff =  0.0236

 ******** Run number   2 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.
```

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0100
2	1100.00	0.0200
3	1000.00	0.0300
4	900.00	0.0400

Degradation rate is: 0.10800

Maximum restoration from decon is : 80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

Unit 1 preparation coeff = 0.8755
Unit 2 preparation coeff = 1.0116
Unit 3 preparation coeff = 1.2040
Unit 4 preparation coeff = 0.9445

Power of each unit at end of the planning window:
Unit 1 will be at 5.60 STAPOWs.
Unit 2 will be at 3.44 STAPOWs.
Unit 3 will be at 2.10 STAPOWs.
Unit 4 will be at 1.26 STAPOWs.

Unit 1 will violate threshold (600.00) at hour 8.38.

Unit 2 will violate threshold (550.00) at hour 8.35.

Unit 3 will violate threshold (500.00) at hour 8.33.

Unit 4 will violate threshold (450.00) at hour 8.31.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	2.00	0.20	2.60	0.20	5.01	7
3	5.01	0.46	2.20	0.46	8.13	6

```
   1       8.13       0.25       2.35       0.10       10.83        6
   2      10.83       0.04       2.80       0.04       13.71        6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1080.0940; Restore Coeff =  0.2498
 Unit  2 Final Power =  959.6998; Restore Coeff =  0.3139
 Unit  3 Final Power =  937.5503; Restore Coeff =  0.1408
 Unit  4 Final Power =  896.0966; Restore Coeff =  0.0068

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                     Init       Decon      Final
 Unit      Start     Move       Time       Move       Finish
Site
   4       2.00      0.20       1.95       0.20        4.36        7
   3       4.36      0.46       1.65       0.46        6.93        6
   1       6.93      0.25       1.76       0.10        9.04        6
   2       9.04      0.04       2.10       0.04       11.23        6

 Total time used (in hours) for decon operations is   9.23
 Unit  1 Final Power =  975.7171; Restore Coeff =  0.1998
 Unit  2 Final Power =  828.7646; Restore Coeff =  0.2397
 Unit  3 Final Power =  890.0870; Restore Coeff =  0.1138
 Unit  4 Final Power =  892.1675; Restore Coeff =  0.0068

 *********Fraction of full decon realized is: 0.500*********

 Decontamination Scheme:
                     Init       Decon      Final
 Unit      Start     Move       Time       Move       Finish    Site
   4       3.06      0.20       1.30       0.20        4.76        7
   3       4.76      0.46       1.10       0.46        6.78        6
   1       6.78      0.25       1.18       0.10        8.31        6
   2       8.31      0.04       1.40       0.04        9.80        6

 Total time used (in hours) for decon operations is   6.74
 Unit  1 Final Power =  875.2029; Restore Coeff =  0.1941
 Unit  2 Final Power =  737.9025; Restore Coeff =  0.2099
 Unit  3 Final Power =  815.1511; Restore Coeff =  0.1307
 Unit  4 Final Power =  829.9969; Restore Coeff =  0.0424

 *********Fraction of full decon realized is: 0.250*********

 Decontamination Scheme:
                     Init       Decon      Final
 Unit      Start     Move       Time       Move       Finish
Site
   4       4.85      0.20       0.65       0.20        5.90        7
   3       5.90      0.46       0.55       0.46        7.37        6
   1       7.37      0.25       0.59       0.10        8.31        6
   2       8.31      0.04       0.70       0.04        9.10        6
```

```
 Total time used (in hours) for decon operations is   4.25
 Unit  1 Final Power =  743.1533; Restore Coeff =  0.2177
 Unit  2 Final Power =  637.0607; Restore Coeff =  0.2099
 Unit  3 Final Power =  688.8149; Restore Coeff =  0.1786
 Unit  4 Final Power =  693.0176; Restore Coeff =  0.1044

 ******** Run number   3 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#     BIP      Attrition Rate

    1      1200.00        0.0100
    2      1100.00        0.0200
    3      1000.00        0.0300
    4       900.00        0.0400

 Degradation rate is: 0.19980

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at    0.08 STAPOWs.
 Unit 2 will be at    0.05 STAPOWs.
 Unit 3 will be at    0.03 STAPOWs.
 Unit 4 will be at    0.02 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour   5.47.

 Unit  2 will violate threshold ( 550.00) at hour   5.47.
```

```
Unit  3 will violate threshold ( 500.00) at hour   5.47.

Unit  4 will violate threshold ( 450.00) at hour   5.47.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  4        2.00     0.20      2.60      0.20        5.01       7
  3        5.01     0.46      2.20      0.46        8.13       6
  1        8.13     0.25      2.35      0.10       10.83       6
  2       10.83     0.04      2.80      0.04       13.71       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1026.8840; Restore Coeff =  0.4774
Unit  2 Final Power =  915.3042; Restore Coeff =  0.5878
Unit  3 Final Power =  900.0640; Restore Coeff =  0.2669
Unit  4 Final Power =  892.8454; Restore Coeff =  0.0125

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  4        2.00     0.20      1.95      0.20        4.36       7
  3        4.36     0.46      1.65      0.46        6.93       6
  1        6.93     0.25      1.76      0.10        9.04       6
  2        9.04     0.04      2.10      0.04       11.23       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power =  835.5087; Restore Coeff =  0.3813
Unit  2 Final Power =  678.4561; Restore Coeff =  0.4540
Unit  3 Final Power =  812.0843; Restore Coeff =  0.2148
Unit  4 Final Power =  885.6031; Restore Coeff =  0.0125

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish
Site
  4        2.00     0.20      1.30      0.20        3.71       7
  3        3.71     0.46      1.10      0.46        5.73       6
  1        5.73     0.25      1.18      0.10        7.25       6
  2        7.25     0.04      1.40      0.04        8.74       6

Total time used (in hours) for decon operations is   6.74
```

```
 Unit  1 Final Power =  761.1385; Restore Coeff =  0.2886
 Unit  2 Final Power =  604.3409; Restore Coeff =  0.3279
 Unit  3 Final Power =  776.6176; Restore Coeff =  0.1636
 Unit  4 Final Power =  878.4196; Restore Coeff =  0.0125

 *********Fraction of full decon realized is: 0.250*********

 Decontamination Scheme:
                     Init      Decon     Final
 Unit      Start     Move      Time      Move       Finish    Site
   4       2.00      0.20      0.65      0.20        3.06       7
   3       3.06      0.46      0.55      0.46        4.53       6
   1       4.53      0.25      0.59      0.10        5.46       6
   2       5.46      0.04      0.70      0.04        6.25       6

 Total time used (in hours) for decon operations is   4.25
 Unit  1 Final Power =  774.2122; Restore Coeff =  0.1982
 Unit  2 Final Power =  633.2813; Restore Coeff =  0.2124
 Unit  3 Final Power =  786.1617; Restore Coeff =  0.1133
 Unit  4 Final Power =  871.2944; Restore Coeff =  0.0125

 ******** Run number   4 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0300
    4        900.00         0.0400

 Degradation rate is: 3.46570

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
```

```
Unit  2 preparation coeff =  1.0116
Unit  3 preparation coeff =  1.2040
Unit  4 preparation coeff =  0.9445
```

PERCENT CHANGE IN RESULTS
WITH ASSOCIATED CHANGE IN PARAMETERS

Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School

<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 10

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	8	20	10	10
2	1	5	5	30
3	18	20	20	0
4	31	10	10	20

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP
1	500.00
2	400.00
3	300.00
4	350.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
2	.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37
3	.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
4	.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0200
2	1100.00	0.0200

```
    3       1000.00          0.0300
    4        900.00          0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  214.88 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  22.33.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4       13.46    0.20      2.60      0.20       16.46       7
   3       16.46    0.46      2.20      0.46       19.58       6
   1       19.58    0.25      2.35      0.10       22.28       6
   2       22.28    0.04      2.80      0.04       25.17       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1092.5890; Restore Coeff =  0.2126
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  913.5319; Restore Coeff =  0.2163
 Unit  4 Final Power =  833.6650; Restore Coeff =  0.1474

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                    Init      Decon     Final
```

```
Unit      Start     Move      Time      Move      Finish    Site
  4       15.25     0.20      1.95      0.20      17.60       7
  3       17.60     0.46      1.65      0.46      20.17       6
  1       20.17     0.25      1.76      0.10      22.28       6
  2       22.28     0.04      2.10      0.04      24.47       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power =  956.6230; Restore Coeff =  0.2214
Unit  2 Final Power =  854.7066; Restore Coeff =  0.2099
Unit  3 Final Power =  795.5067; Restore Coeff =  0.2390
Unit  4 Final Power =  729.7942; Restore Coeff =  0.1832

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       17.03     0.20      1.30      0.20      18.74       7
  3       18.74     0.46      1.10      0.46      20.76       6
  1       20.76     0.25      1.18      0.10      22.28       6
  2       22.28     0.04      1.40      0.04      23.77       6

Total time used (in hours) for decon operations is   6.74
Unit  1 Final Power =  828.9865; Restore Coeff =  0.2302
Unit  2 Final Power =  737.9025; Restore Coeff =  0.2099
Unit  3 Final Power =  675.7469; Restore Coeff =  0.2619
Unit  4 Final Power =  610.1322; Restore Coeff =  0.2196

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       17.35     0.20      0.65      0.20      18.41       7
  3       18.41     0.46      0.55      0.46      19.88       6
  1       19.88     0.25      0.59      0.10      20.81       6
  2       20.81     0.04      0.70      0.04      21.60       6

Total time used (in hours) for decon operations is   4.25
Unit  1 Final Power =  744.3559; Restore Coeff =  0.2170
Unit  2 Final Power =  666.9369; Restore Coeff =  0.1913
Unit  3 Final Power =  592.7671; Restore Coeff =  0.2551
Unit  4 Final Power =  521.2314; Restore Coeff =  0.2261

******** Run number   2 **********


Unit ready time is  1.00 hours after start.

NBC Attack time is  2.00 hours after start.

TOE attrition initiates at  8.00 hours.
```

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0100
2	1100.00	0.0400
3	1000.00	0.0300
4	900.00	0.0400

Degradation rate is: 0.02000

Maximum restoration from decon is : 80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

Unit 1 preparation coeff = 0.8755
Unit 2 preparation coeff = 1.0116
Unit 3 preparation coeff = 1.2040
Unit 4 preparation coeff = 0.9445

Power of each unit at end of the planning window:
Unit 1 will be at 320.56 STAPOWs.
Unit 2 will be at 88.51 STAPOWs.
Unit 3 will be at 120.03 STAPOWs.
Unit 4 will be at 72.41 STAPOWs.

Unit 1 will violate threshold (600.00) at hour 27.10.

Unit 2 will violate threshold (550.00) at hour 17.55.

Unit 3 will violate threshold (500.00) at hour 19.46.

Unit 4 will violate threshold (450.00) at hour 17.55.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	8.68	0.20	2.60	0.20	11.69	7
3	11.69	0.46	2.20	0.46	14.81	6

```
  1      14.81      0.25      2.35      0.10      17.51       6
  2      17.51      0.04      2.80      0.04      20.40       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1132.2390; Restore Coeff =  0.1164
Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
Unit  3 Final Power =  944.1558; Restore Coeff =  0.1227
Unit  4 Final Power =  871.3855; Restore Coeff =  0.0542

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       10.47     0.20      1.95      0.20      12.83       7
  3       12.83     0.46      1.65      0.46      15.40       6
  1       15.40     0.25      1.76      0.10      17.51       6
  2       17.51     0.04      2.10      0.04      19.70       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power = 1050.6280; Restore Coeff =  0.1228
Unit  2 Final Power =  854.7066; Restore Coeff =  0.2099
Unit  3 Final Power =  864.5635; Restore Coeff =  0.1447
Unit  4 Final Power =  808.1100; Restore Coeff =  0.0886

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       12.26     0.20      1.30      0.20      13.96       7
  3       13.96     0.46      1.10      0.46      15.98       6
  1       15.98     0.25      1.18      0.10      17.51       6
  2       17.51     0.04      1.40      0.04      19.00       6

Total time used (in hours) for decon operations is   6.74
Unit  1 Final Power =  967.6511; Restore Coeff =  0.1292
Unit  2 Final Power =  737.9024; Restore Coeff =  0.2099
Unit  3 Final Power =  772.9084; Restore Coeff =  0.1669
Unit  4 Final Power =  717.2100; Restore Coeff =  0.1235

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       14.04     0.20      0.65      0.20      15.10       7
  3       15.10     0.46      0.55      0.46      16.57       6
  1       16.57     0.25      0.59      0.10      17.51       6
  2       17.51     0.04      0.70      0.04      18.30       6

Total time used (in hours) for decon operations is   4.25
```

```
 Unit  1 Final Power =  884.5756; Restore Coeff =  0.1356
 Unit  2 Final Power =  637.0607; Restore Coeff =  0.2099
 Unit  3 Final Power =  674.3796; Restore Coeff =  0.1892
 Unit  4 Final Power =  608.4502; Restore Coeff =  0.1591

 ******** Run number   3 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00         0.0100
    2       1100.00         0.0200
    3       1000.00         0.0600
    4        900.00         0.0400

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at   36.15 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  15.16.
```

```
Unit  4 will violate threshold ( 450.00) at hour  17.55.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  4       13.46     0.20      2.60      0.20       16.46       7
  3       16.46     0.46      2.20      0.46       19.58       6
  1       19.58     0.25      2.35      0.10       22.28       6
  2       22.28     0.04      2.80      0.04       25.17       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1109.2460; Restore Coeff =  0.1687
Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
Unit  3 Final Power =  886.8640; Restore Coeff =  0.3245
Unit  4 Final Power =  833.6650; Restore Coeff =  0.1474

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  4       12.35     0.20      1.95      0.20       14.70       7
  3       14.70     0.46      1.65      0.46       17.27       6
  1       17.27     0.25      1.76      0.10       19.39       6
  2       19.39     0.04      2.10      0.04       21.57       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power = 1029.5440; Restore Coeff =  0.1433
Unit  2 Final Power =  888.8326; Restore Coeff =  0.1734
Unit  3 Final Power =  777.0060; Restore Coeff =  0.2672
Unit  4 Final Power =  775.6598; Restore Coeff =  0.1253

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  4       13.00     0.20      1.30      0.20       14.70       7
  3       14.70     0.46      1.10      0.46       16.72       6
  1       16.72     0.25      1.18      0.10       18.25       6
  2       18.25     0.04      1.40      0.04       19.74       6

Total time used (in hours) for decon operations is   6.74
Unit  1 Final Power =  955.4028; Restore Coeff =  0.1373
Unit  2 Final Power =  807.6725; Restore Coeff =  0.1592
Unit  3 Final Power =  670.8204; Restore Coeff =  0.2672
```

```
 Unit  4 Final Power =  699.2292; Restore Coeff =  0.1382

 *********Fraction of full decon realized is: 0.250*********

 Decontamination Scheme:
                     Init      Decon     Final
 Unit      Start     Move      Time      Move       Finish    Site
   4       13.65     0.20      0.65      0.20       14.70       7
   3       14.70     0.46      0.55      0.46       16.17       6
   1       16.17     0.25      0.59      0.10       17.11       6
   2       17.11     0.04      0.70      0.04       17.90       6

 Total time used (in hours) for decon operations is   4.25
 Unit  1 Final Power =  892.8929; Restore Coeff =  0.1313
 Unit  2 Final Power =  748.7128; Restore Coeff =  0.1450
 Unit  3 Final Power =  579.1461; Restore Coeff =  0.2672
 Unit  4 Final Power =  619.8997; Restore Coeff =  0.1511

 ******** Run number   4 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00        0.0100
    2       1100.00        0.0200
    3       1000.00        0.0300
    4        900.00        0.0800

 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445
```

```
Power of each unit at end of the planning window:
Unit 1 will be at  320.56 STAPOWs.
Unit 2 will be at  196.97 STAPOWs.
Unit 3 will be at  120.03 STAPOWs.
Unit 4 will be at   14.62 STAPOWs.

Unit  1 will violate threshold ( 600.00) at hour  27.10.

Unit  2 will violate threshold ( 550.00) at hour  22.33.

Unit  3 will violate threshold ( 500.00) at hour  19.46.

Unit  4 will violate threshold ( 450.00) at hour  13.73.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                  Init      Decon     Final
Unit     Start    Move      Time      Move       Finish    Site
  4      13.46    0.20      2.60      0.20       16.46       7
  3      16.46    0.46      2.20      0.46       19.58       6
  1      19.58    0.25      2.35      0.10       22.28       6
  2      22.28    0.04      2.80      0.04       25.17       6

Total time used (in hours) for decon operations is  11.71
Unit  1 Final Power = 1109.2460; Restore Coeff =  0.1687
Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
Unit  3 Final Power =  913.5319; Restore Coeff =  0.2163
Unit  4 Final Power =  810.6303; Restore Coeff =  0.2237

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:
                  Init      Decon     Final
Unit     Start    Move      Time      Move       Finish    Site
  4      13.53    0.20      1.95      0.20       15.88       7
  3      15.88    0.46      1.65      0.46       18.45       6
  1      18.45    0.25      1.76      0.10       20.57       6
  2      20.57    0.04      2.10      0.04       22.75       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power = 1016.6670; Restore Coeff =  0.1562
Unit  2 Final Power =  874.6633; Restore Coeff =  0.1882
Unit  3 Final Power =  819.2262; Restore Coeff =  0.2047
Unit  4 Final Power =  699.3054; Restore Coeff =  0.2261

*********Fraction of full decon realized is: 0.500*********
```

```
 Decontamination Scheme:
                      Init       Decon      Final
 Unit      Start      Move       Time       Move        Finish    Site
   4       13.53      0.20       1.30       0.20        15.23       7
   3       15.23      0.46       1.10       0.46        17.25       6
   1       17.25      0.25       1.18       0.10        18.78       6
   2       18.78      0.04       1.40       0.04        20.27       6

 Total time used (in hours) for decon operations is   6.74
 Unit  1 Final Power =  946.7518; Restore Coeff =  0.1431
 Unit  2 Final Power =  798.0797; Restore Coeff =  0.1658
 Unit  3 Final Power =  745.5347; Restore Coeff =  0.1919
 Unit  4 Final Power =  603.7383; Restore Coeff =  0.2261

 *********Fraction of full decon realized is: 0.250*********

 Decontamination Scheme:
                      Init       Decon      Final
 Unit      Start      Move       Time       Move        Finish    Site
   4       13.53      0.20       0.65       0.20        14.58       7
   3       14.58      0.46       0.55       0.46        16.05       6
   1       16.05      0.25       0.59       0.10        16.99       6
   2       16.99      0.04       0.70       0.04        17.78       6

 Total time used (in hours) for decon operations is   4.25
 Unit  1 Final Power =  895.4228; Restore Coeff =  0.1300
 Unit  2 Final Power =  751.5303; Restore Coeff =  0.1435
 Unit  3 Final Power =  688.1606; Restore Coeff =  0.1791
 Unit  4 Final Power =  521.2315; Restore Coeff =  0.2261

 ******** Run number   5 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1       1200.00        0.0100
    2       1100.00        0.0200
```

```
    3       1000.00          0.0300
    4        900.00          0.0400

 Degradation rate is: 0.04000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  127.75 STAPOWs.
 Unit 2 will be at   78.50 STAPOWs.
 Unit 3 will be at   47.83 STAPOWs.
 Unit 4 will be at   28.86 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  17.06.

 Unit  2 will violate threshold ( 550.00) at hour  15.55.

 Unit  3 will violate threshold ( 500.00) at hour  14.47.

 Unit  4 will violate threshold ( 450.00) at hour  13.66.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                   Init      Decon     Final
 Unit      Start   Move      Time      Move       Finish    Site
   4        6.68   0.20      2.60      0.20        9.69       7
   3        9.69   0.46      2.20      0.46       12.81       6
   1       12.81   0.25      2.35      0.10       15.51       6
   2       15.51   0.04      2.80      0.04       18.40       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1106.6010; Restore Coeff =  0.1753
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  935.3583; Restore Coeff =  0.1471
 Unit  4 Final Power =  868.0483; Restore Coeff =  0.0613

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                   Init      Decon     Final
```

```
Unit      Start     Move      Time      Move      Finish    Site
  4        8.47     0.20      1.95      0.20      10.83       7
  3       10.83     0.46      1.65      0.46      13.40       6
  1       13.40     0.25      1.76      0.10      15.51       6
  2       15.51     0.04      2.10      0.04      17.70       6

Total time used (in hours) for decon operations is   9.23
Unit  1 Final Power =  988.1649; Restore Coeff =  0.1861
Unit  2 Final Power =  854.7067; Restore Coeff =  0.2099
Unit  3 Final Power =  838.6376; Restore Coeff =  0.1782
Unit  4 Final Power =  804.1122; Restore Coeff =  0.0929

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       10.26     0.20      1.30      0.20      11.96       7
  3       11.96     0.46      1.10      0.46      13.98       6
  1       13.98     0.25      1.18      0.10      15.51       6
  2       15.51     0.04      1.40      0.04      17.00       6

Total time used (in hours) for decon operations is   6.74
Unit  1 Final Power =  871.2532; Restore Coeff =  0.1970
Unit  2 Final Power =  737.9025; Restore Coeff =  0.2099
Unit  3 Final Power =  726.8749; Restore Coeff =  0.2097
Unit  4 Final Power =  697.3374; Restore Coeff =  0.1398

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  4       12.04     0.20      0.65      0.20      13.10       7
  3       13.10     0.46      0.55      0.46      14.57       6
  1       14.57     0.25      0.59      0.10      15.51       6
  2       15.51     0.04      0.70      0.04      16.30       6

Total time used (in hours) for decon operations is   4.25
Unit  1 Final Power =  758.4103; Restore Coeff =  0.2080
Unit  2 Final Power =  637.0607; Restore Coeff =  0.2099
Unit  3 Final Power =  608.6788; Restore Coeff =  0.2415
Unit  4 Final Power =  569.3459; Restore Coeff =  0.1876

******** Run number   6 **********


Unit ready time is  1.00 hours after start.

NBC Attack time is  2.00 hours after start.

TOE attrition initiates at  8.00 hours.
```

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0100
2	1100.00	0.0200
3	1000.00	0.0300
4	900.00	0.0400

Degradation rate is: 0.02000

Maximum restoration from decon is : 80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

Unit 1 preparation coeff = 0.8755
Unit 2 preparation coeff = 1.0116
Unit 3 preparation coeff = 1.2040
Unit 4 preparation coeff = 0.9445

Power of each unit at end of the planning window:
Unit 1 will be at 320.56 STAPOWs.
Unit 2 will be at 196.97 STAPOWs.
Unit 3 will be at 120.03 STAPOWs.
Unit 4 will be at 72.41 STAPOWs.

Unit 1 will violate threshold (600.00) at hour 27.10.

Unit 2 will violate threshold (550.00) at hour 22.33.

Unit 3 will violate threshold (500.00) at hour 19.46.

Unit 4 will violate threshold (450.00) at hour 17.55.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	13.46	0.20	2.60	0.20	16.46	7
3	16.46	0.46	2.20	0.46	19.58	6

1	19.58	0.25	2.35	0.10	22.28	6
2	22.28	0.04	2.80	0.04	25.17	6

Total time used (in hours) for decon operations is 11.71
Unit 1 Final Power = 1109.2460; Restore Coeff = 0.1687
Unit 2 Final Power = 990.0000; Restore Coeff = 0.2099
Unit 3 Final Power = 913.5319; Restore Coeff = 0.2163
Unit 4 Final Power = 833.6650; Restore Coeff = 0.1474

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	15.25	0.20	1.95	0.20	17.60	7
3	17.60	0.46	1.65	0.46	20.17	6
1	20.17	0.25	1.76	0.10	22.28	6
2	22.28	0.04	2.10	0.04	24.47	6

Total time used (in hours) for decon operations is 9.23
Unit 1 Final Power = 998.4109; Restore Coeff = 0.1752
Unit 2 Final Power = 854.7066; Restore Coeff = 0.2099
Unit 3 Final Power = 795.5067; Restore Coeff = 0.2390
Unit 4 Final Power = 729.7942; Restore Coeff = 0.1832

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	17.03	0.20	1.30	0.20	18.74	7
3	18.74	0.46	1.10	0.46	20.76	6
1	20.76	0.25	1.18	0.10	22.28	6
2	22.28	0.04	1.40	0.04	23.77	6

Total time used (in hours) for decon operations is 6.74
Unit 1 Final Power = 891.8302; Restore Coeff = 0.1817
Unit 2 Final Power = 737.9025; Restore Coeff = 0.2099
Unit 3 Final Power = 675.7469; Restore Coeff = 0.2619
Unit 4 Final Power = 610.1322; Restore Coeff = 0.2196

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	17.35	0.20	0.65	0.20	18.41	7
3	18.41	0.46	0.55	0.46	19.88	6
1	19.88	0.25	0.59	0.10	20.81	6
2	20.81	0.04	0.70	0.04	21.60	6

Total time used (in hours) for decon operations is 4.25

```
Unit  1 Final Power =  818.3594; Restore Coeff =  0.1719
Unit  2 Final Power =  666.9369; Restore Coeff =  0.1913
Unit  3 Final Power =  592.7671; Restore Coeff =  0.2551
Unit  4 Final Power =  521.2314; Restore Coeff =  0.2261
```

SENSITIVITY FOR PARTIAL DECON TIMES

Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School

<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 10

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	8	20	10	10
2	1	5	5	30
3	18	20	20	0
4	31	10	10	20

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP

1	500.00
2	400.00
3	300.00
4	350.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
2	.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37
3	.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
4	.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0100
2	1100.00	0.0200
3	1000.00	0.0300
4	900.00	0.0400

```
 Degradation rate is: 0.02000

 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040
 Unit  4 preparation coeff =  0.9445

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.
 Unit 4 will be at   72.41 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 Unit  4 will violate threshold ( 450.00) at hour  17.55.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4       13.46    0.20      2.60      0.20       16.46       7
   3       16.46    0.46      2.20      0.46       19.58       6
   1       19.58    0.25      2.35      0.10       22.28       6
   2       22.28    0.04      2.80      0.04       25.17       6

 Total time used (in hours) for decon operations is  11.71
 Unit  1 Final Power = 1109.2460; Restore Coeff =  0.1687
 Unit  2 Final Power =  990.0000; Restore Coeff =  0.2099
 Unit  3 Final Power =  913.5319; Restore Coeff =  0.2163
 Unit  4 Final Power =  833.6650; Restore Coeff =  0.1474

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   4       15.25    0.20      1.95      0.20       17.60       7
```

3	17.60	0.46	1.65	0.46	20.17	6
1	20.17	0.25	1.76	0.10	22.28	6
2	22.28	0.04	2.10	0.04	24.47	6

Total time used (in hours) for decon operations is 9.23
Unit 1 Final Power = 998.4109; Restore Coeff = 0.1752
Unit 2 Final Power = 854.7066; Restore Coeff = 0.2099
Unit 3 Final Power = 795.5067; Restore Coeff = 0.2390
Unit 4 Final Power = 729.7942; Restore Coeff = 0.1832

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	17.03	0.20	1.30	0.20	18.74	7
3	18.74	0.46	1.10	0.46	20.76	6
1	20.76	0.25	1.18	0.10	22.28	6
2	22.28	0.04	1.40	0.04	23.77	6

Total time used (in hours) for decon operations is 6.74
Unit 1 Final Power = 891.8302; Restore Coeff = 0.1817
Unit 2 Final Power = 737.9025; Restore Coeff = 0.2099
Unit 3 Final Power = 675.7469; Restore Coeff = 0.2619
Unit 4 Final Power = 610.1322; Restore Coeff = 0.2196

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:

Unit	Start	Init Move	Decon Time	Final Move	Finish	Site
4	17.35	0.20	0.65	0.20	18.41	7
3	18.41	0.46	0.55	0.46	19.88	6
1	19.88	0.25	0.59	0.10	20.81	6
2	20.81	0.04	0.70	0.04	21.60	6

Total time used (in hours) for decon operations is 4.25
Unit 1 Final Power = 818.3594; Restore Coeff = 0.1719
Unit 2 Final Power = 666.9369; Restore Coeff = 0.1913
Unit 3 Final Power = 592.7671; Restore Coeff = 0.2551
Unit 4 Final Power = 521.2314; Restore Coeff = 0.2261

SIX UNIT, ONE DECON TEAM SCENARIO

Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School

<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 10

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	31	10	10	20
2	8	20	10	10
3	3	2	2	20
4	33	2	2	30
5	18	20	20	0
6	1	5	5	30

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP
1	500.00
2	400.00
3	300.00
4	350.00
5	400.00
6	410.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10									
1	.00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2	.07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3	.37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4	.18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5	.66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6	.60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7	.14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8	.22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9	.22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10	.34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units										
1	.10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41
2	.70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
3	.52	0.45	0.68	0.42	0.26	0.08	0.38	0.40	0.29	0.24
4	.09	0.15	0.45	0.26	0.74	0.68	0.22	0.30	0.31	0.42
5	.70	0.63	0.52	0.52	0.44	0.46	0.56	0.64	0.65	0.76
6	.64	0.57	0.81	0.55	0.14	0.04	0.50	0.52	0.42	0.37

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

```
Unit#      BIP      Attrition Rate

   1       1200.00         0.0100
   2       1100.00         0.0200
   3       1000.00         0.0300
   4        900.00         0.0400
   5       1050.00         0.0250
   6       1230.00         0.0500

Degradation rate is: 0.02000

Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

Unit  1 preparation coeff =  0.8755
Unit  2 preparation coeff =  1.0116
Unit  3 preparation coeff =  1.2040
Unit  4 preparation coeff =  0.9445
Unit  5 preparation coeff =  0.9651
Unit  6 preparation coeff =  1.0986

Power of each unit at end of the planning window:
Unit 1 will be at  320.56 STAPOWs.
Unit 2 will be at  196.97 STAPOWs.
Unit 3 will be at  120.03 STAPOWs.
Unit 4 will be at   72.41 STAPOWs.
Unit 5 will be at  153.94 STAPOWs.
Unit 6 will be at   66.34 STAPOWs.

Unit  1 will violate threshold ( 600.00) at hour  27.10.

Unit  2 will violate threshold ( 550.00) at hour  22.33.

Unit  3 will violate threshold ( 500.00) at hour  19.46.

Unit  4 will violate threshold ( 450.00) at hour  17.55.

Unit  5 will violate threshold ( 525.00) at hour  20.74.

Unit  6 will violate threshold ( 615.00) at hour  16.19.

En-route decon not possible.

In place decon operation is chosen.

*********Fraction of full decon realized is: 1.000*********

Decontamination Scheme:
                  Init      Decon     Final
Unit      Start   Move      Time      Move       Finish    Site
```

```
  1       8.26      0.27      2.60      0.14      11.26       2
  4      11.26      0.09      2.47      0.09      13.90       1
  5      13.90      0.75      2.20      0.46      17.31       6
  6      17.31      0.04      2.80      0.04      20.20       6
  3      20.20      0.08      1.72      0.08      22.08       6
  2      22.08      0.25      2.35      0.10      24.78       6

Total time used (in hours) for decon operations is  16.52
Unit  1 Final Power = 1169.5050; Restore Coeff =  0.0424
Unit  2 Final Power =  990.0000; Restore Coeff =  0.2501
Unit  3 Final Power =  896.0034; Restore Coeff =  0.3629
Unit  4 Final Power =  850.5787; Restore Coeff =  0.1071
Unit  5 Final Power =  978.0791; Restore Coeff =  0.1583
Unit  6 Final Power = 1097.3530; Restore Coeff =  0.2360

*********Fraction of full decon realized is: 0.750*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  1      11.21      0.27      1.95      0.14      13.56       2
  4      13.56      0.09      1.85      0.09      15.58       1
  5      15.58      0.75      1.65      0.46      18.44       6
  6      18.44      0.04      2.10      0.04      20.63       6
  3      20.63      0.08      1.29      0.08      22.08       6
  2      22.08      0.25      1.76      0.10      24.19       6

Total time used (in hours) for decon operations is  12.98
Unit  1 Final Power = 1100.1870; Restore Coeff =  0.0705
Unit  2 Final Power =  854.7066; Restore Coeff =  0.2501
Unit  3 Final Power =  761.1475; Restore Coeff =  0.3740
Unit  4 Final Power =  757.7502; Restore Coeff =  0.1548
Unit  5 Final Power =  872.9338; Restore Coeff =  0.1880
Unit  6 Final Power =  906.6777; Restore Coeff =  0.2614

*********Fraction of full decon realized is: 0.500*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move      Finish    Site
  1      14.15      0.27      1.30      0.14      15.86       2
  4      15.86      0.09      1.24      0.09      17.26       1
  5      17.26      0.75      1.10      0.46      19.57       6
  6      19.57      0.04      1.40      0.04      21.06       6
  3      21.06      0.08      0.86      0.08      22.08       6
  2      22.08      0.25      1.18      0.10      23.60       6

Total time used (in hours) for decon operations is   9.45
Unit  1 Final Power =  998.3486; Restore Coeff =  0.0991
Unit  2 Final Power =  737.9024; Restore Coeff =  0.2501
Unit  3 Final Power =  640.4191; Restore Coeff =  0.3852
Unit  4 Final Power =  637.1270; Restore Coeff =  0.2034
```

```
Unit  5 Final Power =  754.3249; Restore Coeff =  0.2180
Unit  6 Final Power =  723.1263; Restore Coeff =  0.2870

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  1       15.00     0.27      0.65      0.14       16.05       2
  4       16.05     0.09      0.62      0.09       16.84       1
  5       16.84     0.75      0.55      0.46       18.59       6
  6       18.59     0.04      0.70      0.04       19.38       6
  3       19.38     0.08      0.43      0.08       19.97       6
  2       19.97     0.25      0.59      0.10       20.91       6

Total time used (in hours) for decon operations is   5.91
Unit  1 Final Power =  917.6483; Restore Coeff =  0.1073
Unit  2 Final Power =  680.2540; Restore Coeff =  0.2184
Unit  3 Final Power =  579.1461; Restore Coeff =  0.3417
Unit  4 Final Power =  556.8890; Restore Coeff =  0.2075
Unit  5 Final Power =  679.1967; Restore Coeff =  0.2103
Unit  6 Final Power =  623.5733; Restore Coeff =  0.2649
```

TWO DECON TEAMS, SIX UNITS, PART ONE

Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School

<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 10

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	31	10	10	20
2	8	20	10	10
3	3	2	2	20

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP

1	500.00
2	400.00
3	300.00

Decon time index for truck: 1.00
Decon time index for hvy truck: 1.20
Decon time index for track: 1.50

Distance Table
(Time required to reach sites)

Sites\	Sites 1 to 10								
1 .00	0.07	0.37	0.18	0.66	0.60	0.14	0.22	0.22	0.34
2 .07	0.00	0.30	0.11	0.59	0.53	0.07	0.15	0.16	0.27
3 .37	0.30	0.00	0.26	0.74	0.76	0.30	0.38	0.39	0.51
4 .18	0.11	0.26	0.00	0.48	0.50	0.04	0.12	0.13	0.25
5 .66	0.59	0.74	0.48	0.00	0.19	0.52	0.60	0.43	0.32
6 .60	0.53	0.76	0.50	0.19	0.00	0.46	0.48	0.37	0.32
7 .14	0.07	0.30	0.04	0.52	0.46	0.00	0.08	0.09	0.20
8 .22	0.15	0.38	0.12	0.60	0.48	0.08	0.00	0.17	0.28
9 .22	0.16	0.39	0.13	0.43	0.37	0.09	0.17	0.00	0.11
10 .34	0.27	0.51	0.25	0.32	0.32	0.20	0.28	0.11	0.00
Units									
1 .10	0.14	0.44	0.25	0.73	0.66	0.20	0.28	0.29	0.41
2 .70	0.63	0.82	0.56	0.09	0.10	0.56	0.58	0.47	0.41
3 .52	0.45	0.68	0.42	0.26	0.08	0.38	0.40	0.29	0.24

******** Run number 1 **********

Unit ready time is 1.00 hours after start.

NBC Attack time is 2.00 hours after start.

TOE attrition initiates at 8.00 hours.

Aggregate unit will be stationary through out the planning window.

The planning horizon is 48.00 hours.

The unit power threshold (each unit) is 50.00 percent of its BIP

Unit#	BIP	Attrition Rate
1	1200.00	0.0100
2	1100.00	0.0200
3	1000.00	0.0300

Degradation rate is: 0.02000

```
 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.8755
 Unit  2 preparation coeff =  1.0116
 Unit  3 preparation coeff =  1.2040

 Power of each unit at end of the planning window:
 Unit 1 will be at  320.56 STAPOWs.
 Unit 2 will be at  196.97 STAPOWs.
 Unit 3 will be at  120.03 STAPOWs.

 Unit  1 will violate threshold ( 600.00) at hour  27.10.

 Unit  2 will violate threshold ( 550.00) at hour  22.33.

 Unit  3 will violate threshold ( 500.00) at hour  19.46.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   1      13.32     0.20      2.60      0.20       16.32       7
   2      16.32     0.46      2.35      0.10       19.23       6
   3      19.23     0.23      1.72      0.08       21.26       6

 Total time used (in hours) for decon operations is   7.95
 Unit  1 Final Power = 1140.3750; Restore Coeff =  0.0902
 Unit  2 Final Power = 1017.3190; Restore Coeff =  0.1673
 Unit  3 Final Power =  900.0000; Restore Coeff =  0.3417

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   1      14.55     0.20      1.95      0.20       16.91       7
   2      16.91     0.46      1.76      0.10       19.23       6
   3      19.23     0.23      1.29      0.08       20.83       6

 Total time used (in hours) for decon operations is   6.28
 Unit  1 Final Power = 1060.8620; Restore Coeff =  0.1023
 Unit  2 Final Power =  914.5222; Restore Coeff =  0.1760
 Unit  3 Final Power =  777.0060; Restore Coeff =  0.3417

 *********Fraction of full decon realized is: 0.500*********
```

```
Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  1       15.79     0.20      1.30      0.20       17.50       7
  2       17.50     0.46      1.18      0.10       19.23       6
  3       19.23     0.23      0.86      0.08       20.40       6

Total time used (in hours) for decon operations is   4.61
Unit  1 Final Power =  971.6339; Restore Coeff =  0.1144
Unit  2 Final Power =  813.8115; Restore Coeff =  0.1847
Unit  3 Final Power =  670.8204; Restore Coeff =  0.3417

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  1       17.03     0.20      0.65      0.20       18.09       7
  2       18.09     0.46      0.59      0.10       19.23       6
  3       19.23     0.23      0.43      0.08       19.97       6

Total time used (in hours) for decon operations is   2.94
Unit  1 Final Power =  876.0324; Restore Coeff =  0.1266
Unit  2 Final Power =  716.8450; Restore Coeff =  0.1934
Unit  3 Final Power =  579.1461; Restore Coeff =  0.3417
```

SIX UNIT, TWO DECON TEAM SCENARIO, PART TWO

Land Combat decision program for
NBC Decontamination Operations.

CPT John C. Roberts
U.S. Navy Postgraduate School

<<<<<<<<<<Data Setup for this Series of Runs>>>>>>>>>>

NOTE: Time units are HOURS; distance units are KILOMETERS

Network graph echo is turned off

Location of Decon Sites:

Site#	Node	Time Index
1	32	1.000
2	27	1.000
3	26	1.000
4	19	1.000
5	9	1.000
6	2	1.000
7	20	1.000
8	22	1.000
9	21	1.000
10	14	1.000

Location of decon team is decon site: 7

Location of Units:

Unit#	Node	Trks	Hvy Trks	Tracks
1	33	2	2	30
2	18	20	20	0
3	1	5	5	30

Aggregate unit anticipated point of departure at/near site:
8

Maximum speed of slowest vehicle: 25.00
Decon time per vehicle (base case): 0.0500

Unit #	Initial ABIP

```
        1                350.00
        2                400.00
        3                410.00

 Decon time index for truck:  1.00
 Decon time index for hvy truck:  1.20
 Decon time index for track:  1.50

                          Distance Table
                    (Time required to reach sites)

Sites\                                Sites 1 to 10
1   .00   0.07   0.37   0.18   0.66   0.60   0.14   0.22   0.22   0.34
2   .07   0.00   0.30   0.11   0.59   0.53   0.07   0.15   0.16   0.27
3   .37   0.30   0.00   0.26   0.74   0.76   0.30   0.38   0.39   0.51
4   .18   0.11   0.26   0.00   0.48   0.50   0.04   0.12   0.13   0.25
5   .66   0.59   0.74   0.48   0.00   0.19   0.52   0.60   0.43   0.32
6   .60   0.53   0.76   0.50   0.19   0.00   0.46   0.48   0.37   0.32
7   .14   0.07   0.30   0.04   0.52   0.46   0.00   0.08   0.09   0.20
8   .22   0.15   0.38   0.12   0.60   0.48   0.08   0.00   0.17   0.28
9   .22   0.16   0.39   0.13   0.43   0.37   0.09   0.17   0.00   0.11
10 .34   0.27   0.51   0.25   0.32   0.32   0.20   0.28   0.11   0.00
 Units
1   .09   0.15   0.45   0.26   0.74   0.68   0.22   0.30   0.31   0.42
2   .70   0.63   0.52   0.52   0.44   0.46   0.56   0.64   0.65   0.76
3   .64   0.57   0.81   0.55   0.14   0.04   0.50   0.52   0.42   0.37

 ******** Run number   1 **********


 Unit ready time is  1.00 hours after start.

 NBC Attack time is  2.00 hours after start.

 TOE attrition initiates at  8.00 hours.

 Aggregate unit will be stationary through out the planning
window.

 The planning horizon is 48.00 hours.

 The unit power threshold (each unit) is 50.00 percent of
its BIP

 Unit#      BIP      Attrition Rate

    1        900.00         0.0400
    2       1050.00         0.0250
    3       1230.00         0.0500

 Degradation rate is: 0.02000
```

```
 Maximum restoration from decon is :  80.00 percent.

<<<<<<<<<<Decision results follow>>>>>>>>>>

 Unit  1 preparation coeff =  0.9445
 Unit  2 preparation coeff =  0.9651
 Unit  3 preparation coeff =  1.0986

 Power of each unit at end of the planning window:
 Unit 1 will be at   72.41 STAPOWs.
 Unit 2 will be at  153.94 STAPOWs.
 Unit 3 will be at   66.34 STAPOWs.

 Unit  1 will violate threshold ( 450.00) at hour  17.55.

 Unit  2 will violate threshold ( 525.00) at hour  20.74.

 Unit  3 will violate threshold ( 615.00) at hour  16.19.

 En-route decon not possible.

 In place decon operation is chosen.

 *********Fraction of full decon realized is: 1.000*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   1      10.05     0.14      2.47      0.09       12.74       1
   2      12.74     0.60      2.20      0.46       15.99       6
   3      15.99     0.19      2.80      0.04       19.03       6

 Total time used (in hours) for decon operations is   8.98
 Unit  1 Final Power =  860.0483; Restore Coeff =  0.0832
 Unit  2 Final Power =  986.5089; Restore Coeff =  0.1353
 Unit  3 Final Power = 1107.0000; Restore Coeff =  0.2099

 *********Fraction of full decon realized is: 0.750*********

 Decontamination Scheme:
                    Init      Decon     Final
 Unit      Start    Move      Time      Move       Finish    Site
   1      11.21     0.14      1.85      0.09       13.29       1
   2      13.29     0.60      1.65      0.46       15.99       6
   3      15.99     0.19      2.10      0.04       18.33       6

 Total time used (in hours) for decon operations is   7.12
 Unit  1 Final Power =  796.1417; Restore Coeff =  0.1071
 Unit  2 Final Power =  907.6373; Restore Coeff =  0.1449
 Unit  3 Final Power =  955.7174; Restore Coeff =  0.2099

 *********Fraction of full decon realized is: 0.500*********
```

```
Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  1       12.38     0.14      1.24      0.09       13.84       1
  2       13.84     0.60      1.10      0.46       15.99       6
  3       15.99     0.19      1.40      0.04       17.63       6

Total time used (in hours) for decon operations is   5.25
Unit  1 Final Power =  715.7983; Restore Coeff =  0.1312
Unit  2 Final Power =  826.3339; Restore Coeff =  0.1545
Unit  3 Final Power =  825.1091; Restore Coeff =  0.2099

*********Fraction of full decon realized is: 0.250*********

Decontamination Scheme:
                    Init      Decon     Final
Unit      Start     Move      Time      Move       Finish    Site
  1       13.55     0.14      0.62      0.09       14.39       1
  2       14.39     0.60      0.55      0.46       15.99       6
  3       15.99     0.19      0.70      0.04       16.93       6

Total time used (in hours) for decon operations is   3.38
Unit  1 Final Power =  624.7593; Restore Coeff =  0.1556
Unit  2 Final Power =  744.3990; Restore Coeff =  0.1642
Unit  3 Final Power =  712.3497; Restore Coeff =  0.2099
```

APPENDIX D
INPUT DATA

This appendix contains all input files to the model for the base case scenario. All records are explained. The field widths are shown under the column headings provided.

DOS file name is MAP.DAT

This file contains 145 records. There are three fields in each reord. The first record has the number of nodes, the starting node, and the ending node. The other 144 records contain information about each arc as follows; tail node, head node, distance (kilometers), and trafficability constant (0 to 1).

```
            (Column)
12345678901234567890123456789 0
         34          1          34
          1          2  1.11.000
          1          8  1.41.000
          2          3  2.01.000
          2          9  2.6 .200
          2         10  3.5 .200
          3          4  2.21.000
          3         10  2.5 .200
          4          5  1.31.000
          4         10  1.91.000
          4         11  1.8 .800
          5          6  1.11.000
          5         11  1.3 .800
          5         12  1.31.000
          6         12  1.91.000
          6          7  1.6 .800
          7         12  2.2 .800
          7         13  1.8 .800
          8          9  1.7 .800
          8         18  1.8 .200
          9         10  2.7 .200
          9         14  1.6 .200
          9         18  2.2 .200
          9         19  2.4 .200
         10         11  1.31.000
         10         14  1.6 .800
         10         15  1.7 .200
         11         12  1.2 .800
         11         15  1.61.000
```

```
11          16   1.91.000
12          13   1.6 .800
12          16   1.51.000
13          16   2.0 .200
13          17   1.8 .200
14          15   1.61.000
14          19   2.1 .200
15          16   1.5 .800
15          21   1.0 .800
16          17   2.7 .200
16          23   2.11.000
16          24   1.9 .200
17          24   1.31.000
18          19   2.6 .200
18          26   2.6 .200
18          31   4.3 .200
19          20   1.11.000
19          26   1.3 .200
20          21   2.21.000
20          22   2.01.000
20          27   1.71.000
20          28   2.1 .200
21          22   1.0 .200
22          23   1.2 .800
22          29   1.3 .800
23          24   1.71.000
23          25   1.81.000
23          29   0.81.000
24          25   1.6 .800
25          30   1.1 .800
26          27   1.5 .200
26          31   3.0 .200
27          28   1.9 .200
27          31   2.7 .800
27          32   1.71.000
27          33   2.6 .200
28          29   2.0 .200
28          33   1.8 .200
28          34   2.2 .200
29          34   2.31.000
30          34   2.21.000
31          32   2.61.000
32          33   1.7 .800
33          34   2.2 .200
```

DOS file name is GENERAL.DAT

The first three records are as follows. Record one contains; the number of decon missions before more water is required, and the decon site closest to the aggregate units point of departure (if applicable).

The second record contains the unit ready time, the NBC attack time, the attrition time, the time of aggregate unit move (or -1. if no move), and the planning horizon. All times are in hours from the start. The third record contains; the maximum speed of the slowest vehicle (km/hr), the fraction of BIP to be used for the threshold, the degradation coefficient, and the base decon time per vehicle (in hours). Each succeeding record contains information for each unit as follows; unit ABIP, unit BIP, and attrition rate. It is assumed each unit is in order relative to unit number (i.e., unit 1, unit 2, etc.).

```
              (Column)
12345678901234567890123456789O
  3  8
  1.00  2.00  8.00 -1.00 48.00
 25.00  0.50 0.020 0.050
  500.00 1200.00 0.010
  400.00 1100.00 0.020
  300.00 1000.00 0.030
  350.00  900.00 0.040
```

DOS file name is SITES.DAT

There is one record for each decon site. The record contains the node location and the site attribute. The site attribute is used to indicate the decon time at this site relative to the other sites. It is assumed each site record is in order relative to site number.

```
(Column)
1234567
 32 1.0
 27 1.0
 26 1.0
 19 1.0
  9 1.0
  2 1.0
 20 1.0
 22 1.0
 21 1.0
 14 1.0
```

DOS file name is UNITS.DAT

The first record is the initial decon site loaction of the decon team. Each succeeding record contains information about each unit as follows; node location, number of trucks, number of heavy trucks, number of tracks.

```
(Column)
123456789012
 10
  8 20 10 10
  1  5  5 30
 18 20 20  0
 31 10 10 20
```

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